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J. F. KELLY, *Editor*

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Trend of the Times in Iron and Steel

1st: A Better Finished Product.
2nd: Less Equipment, More Tonnage.

The path of the Steel Maker today becomes more winding, more uphill than at any in his history. He is confronted continuously with new problems which embrace processes, production, maintenance and there will be no end, no stopping off place, he will be required everlastingly to meet new requirements and this, in plain words, is what is termed "progress in our industry."

One of the most important problems that every Steel Maker must face in the future is a better finished product. To meet this new condition there must naturally be an improvement in Blast Furnace methods, improved practices at the open hearth department and rolling mills must be designed and built to produce steel of tolerances and finish that the Steel Buyer demands today to fashion and fabricate his product for ultimate consumption.

The specifications used by the Purchaser of Steel today are most rigorous and exacting. It is the Buyer's prerogative, of course, to demand quality. However, there should be some limit, particularly so when the Steel Industry receives no additional price for the extra quality demanded.

The Steel Industry, like any other manufacturer desires, of course, to operate at a profit. It seems, however, as time goes on to be increasingly difficult to effect this purpose. One large corporation invests for equipment, a hundred million dollars which enables them to produce their product $7.00 per ton cheaper. In the meantime, Steel drops $8.00 per ton and the specifications for finished Steel becomes so exacting, as to make it almost impossible to make even a small margin of profit.

Now what has all this to do with the future trends? Simply and plainly, it means that there will be no retreat so far as the demands for quality are concerned.

In that event it means that the Steel Industry, first, must secure better prices for their product; second, the Steel Industry will be required to improve their present processes and their methods of production.

This means for Blast Furnaces, increasing their capacities from their present tonnages to 1,000 tons and over, which means the use of more steel plates, more refractories, larger stoves, more steam and electric capacities, installations of modern gas and air systems, modern boiler plants, greater capacities in ore handling equipment, transportation systems, iron and slag handling equipment, water and sewer systems, gas cleaning equipment and the use of every type of instrument to regulate and control every mechanical, combustion and electrical operation.

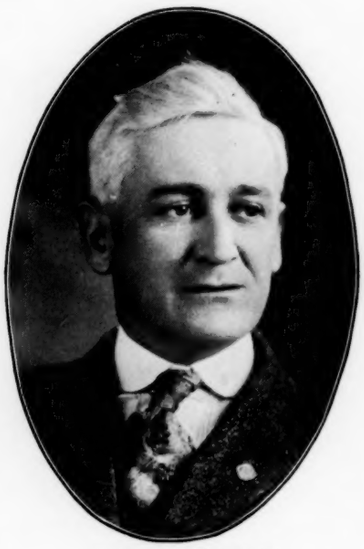
For Open Hearth Plants, furnace sizes must be increased, this means greater hearth area improved roof and back walls and the introduction of all types of automatic combustion control equipment to promote a more rapid and economical rate of melting. It also means a better type of checker insulation. Improvements of this type and character will mean the expenditures of millions of dollars for gas lines and equipment, a better quality of refractories, larger ladle cranes, improvements in metal charging equipment, increased electrical and steam capacities and better systems of material handling.

For Rolling Mills, it means scrapping the existing obsolete steam equipment and replacing this steam equipment with modern electrical drives, which will enable the Steel Mill Operators to produce their finished tonnages more economically and automatically. It also means new rolling mills, built to produce Steel with tolerances and finishes required, new soaking pits and gas producers, modern heating furnaces, improved water systems, modern electric overhead traveling cranes and improved transportation systems, as well as the installation of modern lubricating devices.

The above mentioned forecast includes but the major improvements, additional millions will necessarily have to be spent for the miscellaneous equipment.

Fortunately, the Steel Industry has the financial resources, the trained executives, the experienced operating personnel and the engineering talent to meet the demands indicated in the TREND OF THE TIMES and will continue to occupy its leadership in the Industrial World.

J. J. BOOTH



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A. J. Standing, Elec. Supt., Saucon Plant, Bethlehem Steel Co., Bethlehem, Pa.

J. H. McElhinney, Gen. Supt., Lukens Steel Co., Coatesville, Pa.

D. I. Bohn, Elec. Engr., Aluminum Company of America, Pittsburgh, Pa.

Elbert Lewis, Asst. Elec. Engr., Illinois Steel Co., South Chicago, Ill.

J. C. Reed, Elec. Supt., Bethlehem Steel Co., Steelton, Pa.

C. B. Seagle, Elec. Engr., American Bridge Co., Ambridge, Pa.

W. W. Garrett, Elec. Engr., Tennessee Coal, Iron & R. R. Co., Fairfield, Ala.

E. L. Upp, Elec. Supt., National Tube Co., McKeesport, Pa.

J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Inc., Etna, Pa.

E. A. Aik, A. O. Smith Corp., Milwaukee, Wis.

Charles Schenk, Supt. of Prod., Bethlehem Steel Co., Bethlehem, Pa.

C. M. Myers, Asst. Elec. Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio.

F. W. Cramer, Chief Elec. Engr., Republic Steel Corp., Youngstown, Ohio.

A. A. Stewart, Elec. Supt., Pittsburgh Steel Co., Monessen, Pa.

A. F. Davis, Lincoln Electric Co., Cleveland, Ohio.

A. M. Candy, Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

H. F. Cole, General Electric Co., Pittsburgh, Pa.

ELECTRIC HEAT COMMITTEE

Chairman, C. S. Proudfoot, Gen. Mgr., Vanadium Corp. of America, Niagara Falls, N. Y.

N. C. Bye, Chief Engr., Henry L. Disston & Sons, Inc., Tacony, Philadelphia, Pa.

Wirt Scott, Westinghouse Elec. & Mfg. Co., Mansfield, Ohio.

R. H. Bryant, Elec. Engr., American Steel & Wire Co., Worcester, Mass.

R. W. Heller, Power Engr., Duquesne Light Co., Pittsburgh, Pa.

J. W. Bates, American Sheet & Tin Plate Co., Pittsburgh, Pa.

R. M. Cherry, Engr., General Electric Co., Schenectady, N. Y.

W. W. Wallis, Pres., Pittsburgh Electric Furnace Co., Pittsburgh, Pa.

George H. Schaeffer, Elec. Engr., Carpenter Steel Co., Reading, Pa.

R. J. Hartley, Engr., Simonds Saw & Steel Co., Lockport, N. Y.

E. N. Calhoun, Sales Mgr., Edwin L. Wiegand Co., Pittsburgh, Pa.

C. F. Cone, Engr., Geo. J. Hagan Co., Pittsburgh, Pa.

D. M. Petty, Supt. of Service Dept., Bethlehem Steel Co., Bethlehem, Pa.

F. C. Watson, Elec. Engr., International Nickel Co., Huntington, W. Va.

J. D. Donovan, Elec. and Mech. Supt., Republic Steel Corp., Massillon, Ohio.

Robert L. McIntosh, Indiana Harbor, Ind.

R. F. Benzinger, Vice Pres., Electric Furnace Co., Salem, Ohio.

E. F. Northrup, Vice Pres., Ajax Electrothermic Corp., Trenton, N. J.

S. Arnold, III, Sales Engr., Heroult Electric Furnaces, Pittsburgh, Pa.

H. G. McIlvries, Asst. Chief Engr., American Sheet & Tin Plate Co., Gary, Ind.

W. C. Jahn, Engr., American Sheet & Tin Plate Co., Gary, Ind.

A. W. Duncan, Elec. Supt., Weirton Steel Co., Weirton, W. Va.

C. H. Fielding, Wks. Supt., Rustless Iron Corp., Baltimore, Md.

O. M. Svensson, Engr., Vanadium Corp. of America, Bridgeville, Pa.

ELECTRICAL DEVELOPMENTS COMMITTEE

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J. D. Wright, General Electric Co., Schenectady, N. Y.
R. W. Davis, Allis Chalmers Mfg. Co., Milwaukee, Wis.
W. H. Feldman, Electric Machinery Mfg. Co., Minneapolis, Minn.
B. D. Christian, Crocker-Wheeler Elec. Mfg. Co., Ampere, N. J.

Auxiliary Drives and General Purpose Motors Division

R. H. Wright, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
A. M. McCutcheon, Reliance Elec. & Engr. Co., Cleveland, Ohio.
J. R. Lewis, Crocker-Wheeler Elec. Mfg. Co., Pittsburgh, Pa.
C. C. Hutchins, Elliott Company, Ridgway, Pa.
J. C. Barry, General Electric Co., Erie, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wis.
J. S. Lincoln, Lincoln Electric Co., Cleveland, Ohio.
H. S. Stockdale, Electro Dynamic Co., Pittsburgh, Pa.
L. H. Tipps, U. S. Electrical Mfg. Co., Pittsburgh, Pa.
R. C. Parks, Century Electric Co., Pittsburgh, Pa.

Control Division

N. L. Mortensen, Cutler Hammer, Inc., Milwaukee, Wis.
W. H. Williams, Clark Controller Co., Cleveland, Ohio.
R. G. Widdows, Electric Controller & Mfg. Co., Cleveland, Ohio.
H. A. Winne, General Electric Co., Schenectady, N. Y.
D. W. Deans, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Joseph F. Frese, Monitor Controller Co., Baltimore, Md.
J. S. Rowan, Rowan Controller Co., Baltimore, Md.

Crane Division

G. W. Yanney, Alliance Machine Co., Alliance, Ohio.
F. H. Barnard, Morgan Engineering Co., Alliance, Ohio.
W. C. Heinle, Cleveland Crane & Engineering Co., Wickliffe, Ohio.
T. M. Rees, Manning, Maxwell & Moore, Inc., Pittsburgh, Pa.
Sidney Buckley, Shepard Niles Crane & Hoist Corp., Philadelphia, Pa.
Norman Farrar, Harnischfeger Corp., Milwaukee, Wis.
H. P. O'Neil, Milwaukee Electric Crane & Hoist Co., Milwaukee, Wis.

Transmission Equipment Division

F. E. Fairman, General Electric Co., Pittsburgh, Pa.
N. C. Goin, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Samuel Horelick, Pennsylvania Transformer Co., Pittsburgh, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
P. C. Gunion, I-T-E Circuit Breaker Co., Philadelphia, Pa.
R. F. Gooding, Condit Elec. Mfg. Corp., Pittsburgh, Pa.
William Wray, Allis Chalmers Mfg. Co., Pittsburgh, Pa.
A. F. Alsaker, Delta Star Electric Co., Chicago, Ill.
W. M. McCauley, Sales Mgr., Railway & Industrial Engr. Co., Greensburg, Pa.
L. R. Lewis, Electric Power Equipment Corp., Philadelphia, Pa.
J. J. Mullen, Moloney Electric Co., St. Louis, Mo.
J. S. Livingston, Schweitzer & Conrad, Inc., Chicago Ill.
L. B. Gawthrop, Electric Service Supplies Co., Philadelphia, Pa.
K. A. Hawley, Locke Insulator Co., Baltimore, Md.
B. M. Jones, Duquesne Light Co., Pittsburgh, Pa.
R. L. Baker, Metropolitan Edison Co., Reading, Pa.
M. E. Noyes, Aluminum Company of America, Pittsburgh, Pa.
H. E. Ransford, G & W Electric Specialties Co., Pittsburgh, Pa.
C. H. Kenney, General Cable Corp., New York, N. Y.
J. J. O'Brien, Okonite Company, Chicago, Ill.
J. S. Rashba, Rockbestos Products Corp., Pittsburgh, Pa.
A. N. Cartwright, West Penn Power Co., Pittsburgh, Pa.
R. F. Mason, International Nickel Corp., New York, N. Y.
L. S. Simkins, Anaconda Wire & Cable Corp., Chicago, Ill.

Generating Equipment Division

R. H. Wright, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Saul Lavine, General Electric Co., Pittsburgh, Pa.
W. H. Powell, Allis Chalmers Mfg. Co., Milwaukee, Wis.
L. O. Gregg, Elliott Company, Pittsburgh, Pa.

Miscellaneous Division

H. E. Slack, Bussmann Mfg. Co., Pittsburgh, Pa.
C. L. Snyder, Appleton Electric Co., Pittsburgh, Pa.
John Bangert, Crouse Hinds Co., Pittsburgh, Pa.
M. S. Robinson, Erie Malleable Iron Co., Chicago, Ill.
A. E. Tregenza, Jefferson Electric Co., Chicago, Ill.
T. P. McGinnis, Pyle National Co., Pittsburgh, Pa.
B. M. Slicting, Trico Fuse Mfg. Co., Milwaukee, Wis.
C. C. Lafferty, National Electric Products Co., Lakewood, Ohio.
W. L. DeCoursey, Economy Fuse & Mfg. Co., Pittsburgh, Pa.
G. L. Stout, Colt's Patent Fire Arms Mfg. Co., Pittsburgh, Pa.

Instruments

R. M. Walker, Bristol Company, Chicago, Ill.
A. R. Richardson, General Electric Co., Philadelphia, Pa.
G. L. Crosby, Roller Smith Co., New York, N. Y.
W. B. Shirk, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
L. D. Joralemon, Weston Electrical Instrument Corp., Philadelphia, Pa.
H. F. Darby, Jr., Jewell Electrical Instrument Co., Philadelphia, Pa.
L. O. Morrow, Esterline-Angus Co., Philadelphia, Pa.
G. D. Conlee, Republic Flow Meters Co., Chicago, Ill.
C. L. Clapper, Brown Instrument Co., Pittsburgh, Pa.
I. M. Stein, Leeds & Northrup Co., Philadelphia, Pa.

PORTABLE ELECTRICAL TOOL COMMITTEE

Chairman, A. L. Reichert, Elec. Supt., Bourne Fuller Co., Cleveland, Ohio.

W. C. Buske, M. M., McConway & Torley Co., Pittsburgh, Pa.
A. F. Jones, Chief Elec., Champion Machine & Forging Co., Cleveland, Ohio.
F. M. Sturgess, Chief Elec., American Steel & Wire Co., Fairfield, Ala.
H. L. Coe, Elec. Engr., Carnegie Steel Co., Mingo Junction, Ohio.
W. C. McClelland, Elec. Supt., Standard Tin Plate Co., Canonsburg, Pa.
George H. McFeaters, Elec. Engr., Lorain Steel Co., Johnstown, Pa.
S. E. McQuigg, Chief Elec., Allegheny Steel Co., Brackenridge, Pa.
P. J. McGrane, Chief Elec., Railway Steel Spring Co., Chicago Heights, Ill.
James Maloney, Chief Elec., Superior Steel Co., Carnegie, Pa.
Henry Molz, Chief Elec., Allegheny River Mining Co., Kittanning, Pa.
J. R. Penman, Elec. Supt., Reading Iron Co., Reading, Pa.

J. S. O'Donovan, Elec. Supt., Spang Chalfant Co., Inc., Etna, Pa.
W. J. Davis, Chief Elec., Scullin Steel Co., St. Louis, Mo.
H. F. Raab, Asst. Elec. Supt., Bethlehem Steel Co., Johnstown, Pa.
D. W. McFayden, Chief Elec., Universal Portland Cement Co., Universal, Pa.
William Anderson, Chief Elec., Sellers Mfg. Co., Chicago, Ill.
James Riles, Elec. Supt., A. M. Byers Co., Pittsburgh, Pa.
J. R. Lytle, Chief Elec., Vulcan Mould & Iron Co., Latrobe, Pa.
James H. Reiners, Elec. Engr., Pittsburgh Screw & Bolt Co., N. S., Pittsburgh, Pa.
George Pfeffer, Elec. Supt., Florence Pipe Foundry & Machine Co., Florence, N. J.
J. C. Ritchey, Elec. Engr., Pressed Steel Car Co., McKees Rocks, Pa.
R. F. Waldo, Distr. Mgr., Ideal Commutator Dresser Co., Pittsburgh, Pa.
H. McFarland, Sales Mgr., Martindale Electric Co., Cleveland, Ohio.

AIR CONDITIONING COMMITTEE

Chairman, T. J. Flaherty, Elec. Supt., American Rolling Mills Co., Ashland, Ky.
R. E. Lewis, Elec. Supt., Youngstown Sheet & Tube Co., Youngstown, Ohio.
J. H. Milliken, American Air Filter Co., Inc., Chicago, Ill.
T. E. Hughes, Asst. to Elec. Supt., Carnegie Steel Co., Duquesne, Pa.
W. B. Rese, Elec. Engr., Great Lakes Steel Corp., Ecorse, Mich.
W. H. Beyerly, Asst. Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.
G. R. Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.
W. S. Hall, Supt. Engr. and Constr., Illinois Steel Co., South Chicago, Ill.
J. E. Sayer, Asst. Chief Elec., Tennessee Coal, Iron & R. R. Co., Ensley, Ala.
G. W. Baumgarten, Asst. Elec. Engr., Carnegie Steel Co., Duquesne, Pa.

TRANSPORTATION COMMITTEE

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C. W. Chappelle, Geo. D. Whitcomb Co., Pittsburgh, Pa.
George H. Criss, H. E. McCoy Co., Pittsburgh, Pa.
A. H. Candee, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
R. S. Richards, Atlas Car Mfg. Co., Cleveland, Ohio.
R. F. Hibbard, Wright Hibbard Electric Truck Corp., Phelps, N. Y.
L. N. Crissman, Electric Storage Battery Co., Pittsburgh, Pa.
J. K. Mahaffey, Edison Storage Battery Co., Pittsburgh, Pa.
G. M. Barker, Philadelphia Storage Battery Co., Pittsburgh, Pa.
E. Coates, Elec. Supt., Republic Steel Corp., Buffalo, N. Y.

SHOP PRACTICES COMMITTEE

Chairman, E. C. Marshall, Elec. Supt., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.
O. H. Meineke, Elec. Supt., Spang Chalfant Co., Inc., Ambridge, Pa.
William Linman, Elec. Foreman, Inland Steel Co., Indiana Harbor, Ind.
George Pfeffer, Elec. Supt., Florence Pipe Foundry & Machine Co., Florence, N. J.
C. M. Thompson, Jr., Prod. Engr., Henry L. Disston & Sons, Inc., Tacony, Philadelphia, Pa.
R. F. Gale, Plant Engr., Midvale Company, Nicetown, Philadelphia, Pa.
W. W. Barefoot, Elec. Supt., Carnegie Steel Co., McKees Rocks, Pa.
C. E. Miller, Elec. Supt., Carnegie Steel Co., Clairton, Pa.
J. S. Murray, Chief Elec. Engr., Follansbee Bros. Co., Toronto, Ohio.
Paul Canney, Elec. Supt., Minnesota Steel Co., Duluth, Minn.
G. N. Hughes, Elec. Supt., Gulf States Steel Co., Alabama City, Ala.
H. S. Harding, Elec. Shop Foreman, Great Lakes Steel Corp., Ecorse, Mich.

COMBUSTION ENGINEERING DIVISION

EXECUTIVE COMMITTEE

Engineering Section Director, Chairman, G. T. Hollet, Comb. Engr., Illinois Steel Co., South Chicago, Ill.
Secretary, T. J. Ess, Comb. Engr., Republic Steel Corp., Massillon, Ohio.
W. N. Flanagan, Spec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
H. V. Flagg, Asst. Comb. Engr., American Rolling Mills Co., Middletown, Ohio.
Martin J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.
J. E. Dunn, Comb. Engr., Republic Steel Corp., Youngstown, Ohio.

Gas Utilization Section

Chairman, F. M. Washburn, Met., Wisconsin Steel Works, South Chicago, Ill.
Walter N. Flanagan, Spec. Engr., Carnegie Steel Co., Pittsburgh, Pa.
A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ind.
F. G. Cutler, Chief Bureau of Steam Engr., Tennessee Coal, Iron & R. R. Co., Ensley, Ala.
J. G. West, Asst. Gen. Mgr., Jones & Laughlin Steel Corp., Pittsburgh, Pa.
A. J. Boynton, Engr., H. A. Brassert & Co., Chicago, Ill.
W. H. Cosgrove, Pres., Gas Combustion Co., Pittsburgh, Pa.
W. E. Bisler, Engr., Combustion Engr. Corp., New York, N. Y.
J. C. Hayes, Engr., Freyn Engineering Co., Chicago, Ill.
Karl L. Landgrebe, Vice Pres., Tennessee Coal, Iron & R. R. Co., Birmingham, Ala.
J. W. Jones, Steam Engr., Wheeling Steel Corp., Portsmouth, Ohio.
Wilfred Sykes, Vice Pres., Inland Steel Co., Chicago, Ill.
W. J. McGurty, Bartlett Hayward Co., Baltimore, Md.
C. W. Hedberg, Research Corp., Bound Brook, N. J.
J. L. Hott, Comb. Engr., Wickwire Spencer Steel Co., Buffalo, N. Y.

Gas Producer Section

Chairman, E. A. Hawk, Steam Engr. Dept., Tennessee Coal, Iron & R. R. Co., Ensley, Ala.
G. R. McDermott, Vice Pres., Chapman Stein Div., Surface Combustion Corp., Toledo, Ohio.
A. L. Foell, Chief Engr., Arthur G. McKee Co., Cleveland, Ohio.
Walter de Fries, Chief Engr., Wm. B. Pollock Co., Youngstown, Ohio.
L. C. Edgar, Chief Engr., Edgar Thompson Works, Carnegie Steel Co., Braddock, Pa.
C. W. Phillips, Gen. M. M., Republic Steel Corp., Warren, Ohio.
L. F. Coffin, Gen. M. M., Bethlehem Steel Co., Sparrows Point, Md.
W. J. Harper, Chief Comb. Engr., Republic Steel Corp., Youngstown, Ohio.
H. C. Seibert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.

W. A. McKee, Comb. Engr., Great Lakes Steel Corp., Ecorse, Mich.

S. M. Jenks, Fuel Engr., American Sheet & Tin Plate Co., Gary, Ind.

Steam Generation and Utilization Section

Chairman, J. D. Donovan, Elec. and Mech. Supt., Republic Steel Corp., Massillon, Ohio.

L. C. Edgar, Chief Engr., Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.

E. W. Trexler, Supt. Mech. Dept., Bethlehem Steel Co., Johnstown, Pa.

J. B. Crane, Engr., Combustion Engineering Corp., Pittsburgh, Pa.

James Rath, Power Dept., National Tube Co., McKeesport, Pa.

E. Kieft, Engr. of Tests, Illinois Steel Co., Gary, Ind.

C. H. Verwohlt, Works Engr., Wheeling Steel Corp., Wheeling, W. Va.

A. L. Penniman, Jr., Supt. Steam Station, Consolidated Gas, Electric, Light & Power Co., Baltimore, Md.

E. C. McDonald, Asst. Steam Engr., Republic Steel Corp., Buffalo, N. Y.

C. H. Williams, Steam Engr. Dept., Carnegie Steel Co., Ohio Works, Youngstown, Ohio.

E. P. Winters, Power Engr., Sloss Sheffield Steel & Iron Co., North Birmingham, Ala.

L. F. Fairthorne, Battelle Memorial Institute, Columbus, Ohio.

Liquid Fuel Section

Chairman, W. J. Harper, Chief Comb. Engr., Republic Steel Corp., Youngstown, Ohio.

F. G. Gasche, Comb. Engr., Buffalo, N. Y.

H. C. Seibert, Comb. Engr., Bethlehem Steel Co., Bethlehem, Pa.

S. Kneass, Engr., Lief Lee Company, Youngstown, Ohio.

A. K. McMillan, Chief Engr., Alex Laughlin & Co., Pittsburgh, Pa.

A. W. Steed, Supt. Maint., American Rolling Mills Co., Middletown, Ohio.

Joseph G. Walsh, Asst. Gen. Supt., Republic Steel Corp., Birmingham, Ala.

Karl H. Marsh, Chief Engr., British Empire Steel Co., Sydney, N. S. Canada.

G. T. Hollett, Comb. Engr., Illinois Steel Co., South Chicago, Ill.

L. Ellman, Vice Pres., M. H. Detrick Co., Pittsburgh, Pa.

Joseph Kennedy, Julian Kennedy Co., Pittsburgh, Pa.

A. L. Culbertson, Distr. Mgr., Rust Engineering Co., Pittsburgh, Pa.

W. R. Culbertson, Sales Engr., Chapman Stein Div., Surface Combustion Corp., Toledo, Ohio.

E. H. Younglove, Johns Manville, Inc., Chicago, Ill.

A. G. Witting, Chief Engr., Illinois Steel Co., Gary, Ind.

John Lehnert, Comb. Engr., Republic Steel Corp., Massillon, Ohio.

C. H. Hunt, Vice Pres., Weirton Steel Corp., Weirton, W. Va.

S. Naismith, Refractory Engr., Illinois Steel Co., South Chicago, Ill.

W. P. Chandler, Jr., Spec. Engr., Blaw Knox Co., Blawnox, Pa.

A. V. Ritts, Chief Engr., Costello Engr. Co., Pittsburgh, Pa.

Instrument and Control Section

Chairman, M. J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.

J. Wallace, M. M., Wheeling Steel Corp., Benwood Works, Wheeling, W. Va.

J. G. Allen, Chief Engr., Carnegie Steel Co., New Castle, Pa.

Geo. M. Coughlin, Combustion Engineer, American Rolling Mill Co., Ashland, Ky.

Carl Fischer, Supt. Light, Heat and Power, Mesta Machine Co., West Homestead, Pa.

R. M. Walker, Distr. Mgr., Bristol Co., Chicago, Ill.

G. D. Conlee, Chief Engr., Republic Flow Meters Co., Chicago, Ill.

H. R. Maxon, Pres., Maxon Premier Burner Co., Muncie, Ind.

J. M. Hopwood, Pres., Hagan Corporation, Pittsburgh, Pa.

C. H. Smoot, Pres., Smoot Engineering Co., New York, N. Y.

J. E. Dunn, Comb. Engr., Republic Steel Corp., Youngstown, Ohio.

M. Stein, Leeds & Northrup Co., Philadelphia, Pa.

C. L. Clapper, Brown Instrument Co., Pittsburgh, Pa.

W. M. Shallcross, Pres., Shallcross Control Systems, Inc., Milwaukee, Wis.

P. S. Dickey, Bailey Meter Co., Cleveland, Ohio.

R. W. Simpson, American Heat Economy Bureau, Inc., Pittsburgh, Pa.

SAFETY ENGINEERING DIVISION

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C. E. Sankey, Chief Safety Director, National Tube Co., Pittsburgh, Pa.

C. L. Baker, Management's Repr., Bethlehem Steel Co., Lackawanna, N. Y.

R. G. Adair, Asst. Works Mgr., American Rolling Mills Co., Butler, Pa.

Earl Blank, Director of Safety, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

A. C. Germain, Safety Director, Minnesota Steel Co., Duluth, Minn.

H. G. Hensel, Safety Engr., Youngstown Sheet & Tube Co., Indiana Harbor, Ind.

F. H. Rowe, Safety Engr., Wheeling Steel Corp., Portsmouth, Ohio.

P. F. Haberstick, Safety Engr., Wheeling Steel Corp., Benwood, W. Va.

J. A. Oartel, Safety Director, Carnegie Steel Co., Pittsburgh, Pa.

J. A. Northwood, Safety Director, Bethlehem Steel Co., Sparrows Point, Md.

P. G. Fenlon, Safety Director, Carnegie Steel Co., Duquesne, Pa.

J. F. Hunter, Safety Engr., Carnegie Steel Co., Pittsburgh, Pa.

F. H. Kittredge, Elec. Supt., Illinois Steel Co., Joliet, Ill.

Stanley Grand Girard, Chief Elec. Engr., Sharon Steel Hoop Co., Sharon, Pa.

G. A. Lamberton, Gen. Foreman, National Tube Co., Lorain, Ohio.

LUBRICATION ENGINEERING DIVISION

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Secretary, T. B. Little, Association of Iron & Steel Electrical Engineers, Pittsburgh, Pa.

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D. B. Geeseman, Gen. Mgr., Standard Tin Plate Co., Canonsburg, Pa.

J. A. Clauss, Chief Engr., Great Lakes Steel Corp., Ecorse, Mich.

Vic Chartner, Chief Engr., Pittsburgh Steel Co., Monessen, Pa.

J. D. Donovan, Elec. and Mech. Supt., Republic Steel Corp., Massillon, Ohio.

J. H. Krehl, Supt. Mech. Dept., Youngstown Sheet & Tube Co., Youngstown, Ohio.

C. A. Bollinger, M. M., American Sheet & Tin Plate Co., New Castle, Pa.

F. J. Binckes, Asst. Chief Engr., Inland Steel Co., Indiana Harbor, Ind.

C. A. Baumann, Chief Mech. Engr., Carnegie Steel Co., Clairton, Pa.

J. C. Green, Asst. Engr., Pittsburgh Crucible Steel Co., Midland, Pa.

F. L. Gray, Lubr. Engr., Illinois Steel Co., Gary, Ind.

C. W. Phillips, Gen. M. M., Republic Steel Corp., Warren, Ohio.

F. C. Hallmark, Gen. M. M., Wheeling Steel Corp., Steubenville, Ohio.

H. G. Gibson, M. M., McKeesport Tin Plate Co., McKeesport, Pa.

C. J. Duby, Asst. Chief Engr., Republic Steel Corp., Warren, Ohio.

Gordon Gage, Supt. Maint., American Rolling Mills Co., Butler, Pa.

Carl S. Walrab, M. M., Calumet Steel Co., Chicago Heights, Ill.

L. A. Wynd, M. M., Keystone Steel & Wire Co., Peoria, Ill.

J. M. Faris, Asst. to Vice Pres., Youngstown Sheet & Tube Co., Youngstown, Ohio.

E. C. Kirkpatrick, Mech. Engr., Steel Company of Canada, Ltd., Montreal, Quebec, Canada.

L. F. Coffin, Gen. M. M., Bethlehem Steel Co., Sparrows Point, Md.

S. N. Roberts, Mech and Elec. Supt., Atlantic Steel Co., Atlanta, Ga.

R. C. Mohler, Distr. Engr., American Steel & Wire Co., Pittsburgh, Pa.

Howard M. Miner, M. M., Follansbee Bros. Co., Toronto, Ohio.

H. F. Martin, M. M., Jones & Laughlin Steel Corp., Aliquippa, Pa.

B. S. Burrell, M. M., Inland Steel Co., Indiana Harbor, Ind.

John F. Pelly, Bethlehem Steel Co., Bethlehem, Pa.

Samuel Roberts, Lubr. Engr., Carnegie Steel Co., Homestead Works, Munhall, Pa.

John M. Husher, Gen. M. M., Pittsburgh Steel Co., Monessen, Pa.

C. R. Weber, Lubr. Engr., Republic Steel Corp., Youngstown, Ohio.

H. J. Mercer, Lubr. Engr., Youngstown Sheet & Tube Co., Campbell, Ohio.

LUBRICANT AND DEVICE DEVELOPMENT COMMITTEE

Chairman, C. C. Pecu, Lubrication Engineer, Bethlehem Steel Co., Lackawanna, N. Y.

Secretary, T. B. Little, Association of Iron & Steel Electrical Engineers, Pittsburgh, Pa.

H. G. Mullen, Grease Sales Supv., Tidewater Oil Sales Corporation, New York, N. Y.

J. M. Lutz, Sales Mgr., Pennsylvania Lubricating Co., Pittsburgh, Pa.

E. W. Beardsley, Sec'y. and Gen. Mgr., The Ohio Grease Company, Loudonville, Ohio.

J. R. Michael, Treas. and Gen. Mgr., Hulbert Oil & Grease Company, Philadelphia, Pa.

L. E. Kohler, Mgr., Lubr. Division, S. F. Bowser & Company, Inc., Fort Wayne, Ind.

K. A. Newman, Lubr. Sales Engr., E. F. Houghton & Company, Philadelphia, Pa.

L. P. Tyler, Tech. Mgr., Vacuum Oil Company, Pittsburgh, Pa.

J. H. Garlough, Lubr. Engr., Valvoline Oil Company, New York, N. Y.

C. E. Sperry, Service Engr., Detroit Lubricator Company, New York, N. Y.

Joseph F. Hall, Asst. Ch. Engr., The Ironsides Company, Columbus, Ohio.

Wm. R. Maize, Sales Engr., Sinclair Refining Co., Cleveland, Ohio.

H. E. Pryor, Sales Engr., Banfield Oil & Grease Co., Etna, Pa.

A. F. Brewer, Mech. Engr., The Texas Company, New York, N. Y.

Foster Holmes, Sales Mgr., Lincoln Engineering Co., St. Louis, Mo.

C. A. Fine, Chg., Inds. Sales, The Alemite Corporation, Chicago, Ill.

Joseph F. King, Sales Mgr., Waverly Oil Works Company, Pittsburgh, Pa.

R. G. Schenck, Sales Engr., Fiske Brothers Refining Co., Cleveland, Ohio.

G. W. Miller, President, American Lubricant Co., Buffalo, N. Y.

H. J. Turner, Distr. Mgr., Sharples Specialty Co., Pittsburgh, Pa.

Philip King, Engineer, Keystone Lubricating Co., Pittsburgh, Pa.

James Graham, Lubr. Engr., Universal Lubricating Co., Cleveland, Ohio.

J. G. McCaw, Ass't. to V. P., The Freedom Oil Works Co., Freedom, Pa.

W. E. Smith, Lubr. Engr., National Refining Co., Cleveland, Ohio.

E. S. Glauch, Mech. Engr., Jos. Dixon Crucible Co., Jersey City, N. J.

R. M. Gordon, President, R. M. Gordon & Company, Pittsburgh, Pa.

F. G. Grassle, Sec'y., Hills-McCanna Company, Chicago, Ill.

R. F. Crego, Sales Engr., Universal Gear Corp., Chicago, Ill.

A. J. Jennings, V. P., Lubrication Devices, Inc., Battle Creek, Mich.

J. G. Griffith, President, J. G. Griffith Company, Pittsburgh, Pa.

Frank B. Godard, Div. Sales Mgr., U. S. Graphite Company, Pittsburgh, Pa.

W. D. Hodson, President, Hodson Corporation, Chicago, Ill.

T. J. Kauffield, Div. Sales Mgr., DeLaval Separator Company, Pittsburgh, Pa.

V. J. Nolan, Distr. Sales Mgr., National Carbon Company, Inc., Pittsburgh, Pa.

F. E. Jacques, Lubr. and Sales Engr., Sun Oil Company, Youngstown, Ohio.

Geo. P. Dempler, President, Geo. P. Dempler Company, Pittsburgh, Pa.

PAPERS AND DISCUSSION

PRESENTED BEFORE THE

COMBUSTION ENGINEERING DIVISION

Association of Iron and Steel Electrical Engineers at the Twenty-Seventh Annual Convention

CLEVELAND, OHIO JUNE 17, 1931

MORNING SESSION

"THE PRACTICAL SIDE OF METALLURGICAL HEAT APPLICATION"

BY

H. DOBRIN, Consulting Fuel Engineer, Pittsburgh, Pa.

"OPEN HEARTH FURNACE CONTROL"

BY

M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

AFTERNOON SESSION

SYMPOSIUM

"ELECTRICAL vs. MECHANICAL DEVICES USED IN COMBUSTION CONTROL OF OPEN HEARTH FURNACES."

Papers Presented By

J. F. SHADGEN, Combustion Engineer, Smoot Engineering Corp., New York, N. Y.
P. S. DICKEY, Research Engineer, Bailey Meter Company, Cleveland, Ohio.
G. D. CONLEE, Engineer, Republic Flow Meters Co., Chicago, Ill.
B. F. KEENE, Leeds & Northrup Co., Philadelphia, Pa.
W. M. SHALLCROSS, President, Shallcross Control Systems Co., Milwaukee, Wis.
R. W. SIMPSON, American Heat Economy Bureau, Inc., Pittsburgh, Pa.

Papers Discussed By

M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.
GEORGE M. COUGHLIN, Combustion Engineer, American Rolling Mill Co., Ashland, Ky.
DR. F. F. FOSS, Assistant to President, Wheeling Steel Corporation, Wheeling, W. Va.
J. F. SHADGEN, Combustion Engineer, Smoot Engineering Corporation, New York, N. Y.
F. E. LEAHY, Combustion Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.
H. B. FLAGG, Assistant Combustion Engineer, American Rolling Mill Company, Middletown, Ohio.
HARRY DOBRIN, Consulting Fuel Engineer, Pittsburgh, Pa.
W. J. HARPER, Chief Combustion Engineer, Republic Steel Corporation, Youngstown, Ohio.
G. D. CONLEE, Engineer, Republic Flow Meters Co., Chicago, Ill.
W. P. CHANDLER, JR., Chief Engineer, Furnace Equipment Dept., Blaw Knox Co., Blawnox, Pa.
W. C. BUELL, JR., Combustion Engineer, Arthur G. McKee Co., Cleveland, Ohio.
L. RUMFORD, Research Laboratory, U. S. Steel Corporation, Kearney, N. J.
LOUIS ELLMAN, Vice President, M. H. Detrick Company, Pittsburgh, Pa.
M. J. BRADLEY, Engineer, Leeds & Northrup Co., Philadelphia, Pa.
WM. R. PAULSEN, Manager, American Heat Economy Bureau, Inc., Pittsburgh, Pa.
H. A. WINNE, Engineer, General Electric Company, Schenectady, N. Y.
H. A. LOPEZ, Engineer, B. F. Sturtevant Co., Pittsburgh, Pa.
EMIL A. VIEROW, Assistant Combustion Engineer, Jones & Laughlin Steel Corporation, Pittsburgh, Pa.

*Electrical versus Mechanical Devices Used In Control and Regulation Engineering**

By J. F. SHADGEN †

Introduction

Last winter an official of your Association approached the writer while in Chicago to prepare a study on the above subject, said study to form a basis for a comprehensive discussion during the next summer meeting.

In order to give real value to an investigation of controversal nature, it is essential to be strictly objective and purely technical. If possible, the commercial bias should be omitted. Therefore it will be endeavored to state the fundamental principles clearly and concisely. We have a given problem and we are to study the adaptability and suitability of certain media and certain devices for the solution of the problem.

Criticism will be in order and constructive suggestions are welcome. The importance of control and regulation in the industry is growing. The exposé of principles and facts will benefit the users of control devices and will help to form correct conclusions.

Analysis of the Process of Regulation

The process of regulation, the sequence of effects and operations constituting a control operation are not clearly understood and we will start with some preliminary definitions.

Regulation means—first a **disturbance,** and second a **correction** to restore the disturbed balance. Some influence, outside or inside, disturbs an element (pressure, speed, volume, voltage, frequency, etc.) of importance in an industrial application. This unbalance must start the **sequence** of operations leading to a correction which reestablishes the desired equilibrium. The complete process demands a **closed cycle** of effects and reactions.

What is meant by these generalities can be illustrated by a simple example. In Figure #1 is shown a pipe P, through which flows a medium at a certain rate under given conditions. It is desired to maintain the pressure constant at point A. The pipe is provided at B with a corrective device (valve, damper, rheostat) which position influences the flow condition of the medium.

To regulate the pressure at A it is necessary to know what this pressure is. Therefore, the first step is to measure it by putting a **metering device** at A —a pressure gauge with finger and dial, or any visible **responsive** indication. Responsive means following instantaneously the changes of pressure at A. This qualification is of importance and will be emphasized later. (See Fig. 2).

To finish the regulating process it is necessary to interpose between the metering device at A and the corrective device at B an intelligent man. This man is told to watch the needle of the gauge carefully and consistently When the pressure variations move the needle away from the set position, indicating that the pressure conditions have been disturbed, the operator grasps the handle of the corrective device and moves it to a new position in such direction as to restore the original setting of the needle and consequently the pressure it indicates. (See Fig. 3).

The man performs an operation requiring skill and judgment. He uses his arm as a power medium to overcome the resistances at B, and his eye guides his hands as the variations of this needle have to be watched as a primary impulse. The skill and discrimination of the operator govern how quickly and how effectively the desired effect will be restored.

The cyclic nature of the entire regulating process is clearly shown by the broken line—1, 2, 3, 4, 5, 6, 7, 8—which starts at 1 and ends at 8 on point A. All these operations take time to occur and more time is required for the effects to reset. One operation can only start unless the preceeding one is well under way. As soon as the needle comes back to the original set point, the complete sequence of one operation is completed.

The above analysis describes hand or manual regulation or control. It brings out the following points:

(a) the sequential nature of the process.
(b) the influence of time in the process.
(c) the skill required to coordinate the movements at B to restore fluctuations at A.

To consistently perform the given task accurately and quickly for twenty-four hours each day is beyond the limits of human nature. Therefore, the tendency has been to develop "machines" for the purpose of accomplishing the task assigned to the man. These machines are called **regulators, controllers or governors.** Their purpose is the substitution of a man (operator) and the study of these devices is called "MACHINE REGULATION" a relatively new line in the art of engineering.

It must be repeated and emphasized that the foundation of the development of these machines is:

(a) Greater accuracy than with the skilled man.
(b) more consistency than with the human man.
(c) higher speed than with the deliberate man.
(d) more reliability than with the emotional man.

Principle of Machine Regulation Cycle

(See Fig. 4).

The regulator is a machine or apparatus interposed between A and B. It is provided with an eye or impulse device C, which meters and balances the variations coming from A. The part C energizes a power device D operating the corrective apparatus at B. The combination C and D is called the regulator. Usually the regulator is built as a unit, but not necessarily so. One thing is evident—that the regulator must be considered in conjunction with the corrective device, as coordination is necessary to make the complete sequence of operations a success.

*Presented before Combustion Engineering Division of A. I. & S. E. E. at Cleveland Convention, June, 1931.

†Combustion Engineer, Smoot Engineering Corporation, New York City.

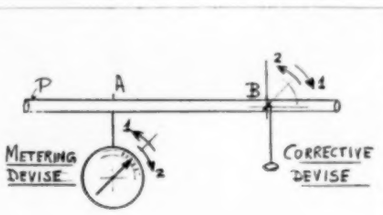


FIG #2

FIG #1

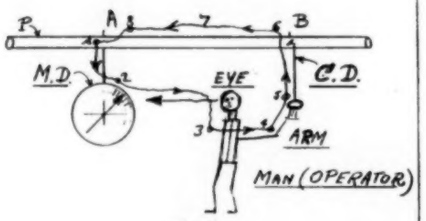


FIG #3

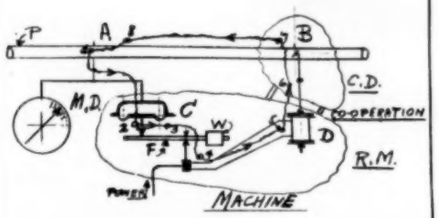
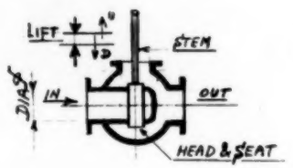


FIG #4



VALVE

FIG #5

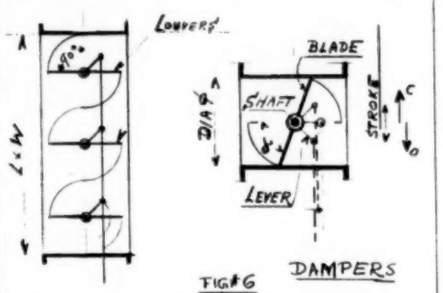


FIG #6 DAMPERS

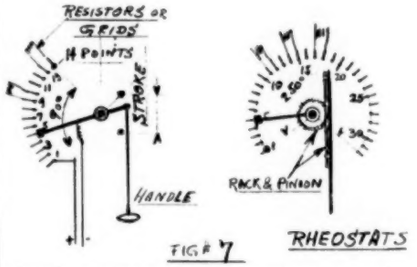


FIG #7 RHEOSTATS

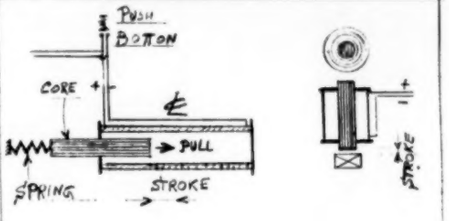
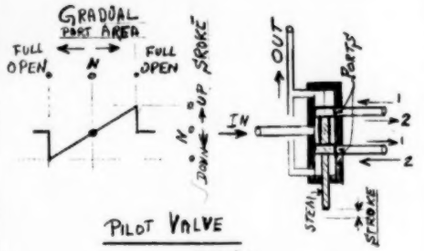
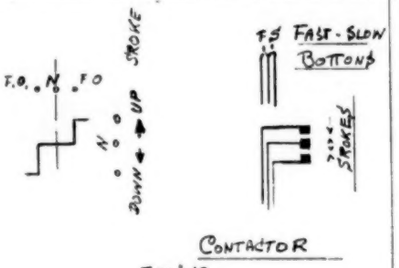


FIG #8 SOLENOID



PILOT VALVE

FIG #9



CONTACTOR

FIG #10

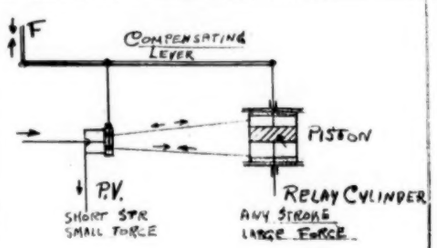


FIG #11

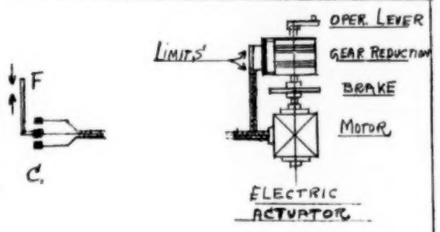


FIG #12

Such a regulator as described above is usually called a "POWER REGULATOR" as it utilizes an outside source of energy to obtain the force required to move B. In literature covering this subject, they are often called **Indirect** or **Relay Regulators.** Direct regulators do not require outside power to do their work. This study limits itself to the further analysis of the **Relay Type Regulators.**

There are two auxiliary types of energy available in modern plants.

1. **Fluid Power,** also called hydraulic energy—air, steam, water or oil under pressure.
2. **Electricity** Current A.C. or D.C., at given voltage and characteristics.

The subject to be discussed is: "Which of these auxiliary power media is best suited for the given characteristics demanded of **Relay Regulating Machines."**

Let us review the main features of all power media available.

Generalities

The fluid media are usually available at 80-100 lbs. per sq. in. All four elements listed above are used in the industries.

Steam has little popularity because it condenses, heats up the apparatus, is messy, demands lubrication, good packing, etc. Furthermore, when used in piston-cylinder machines, it offers an elastic resistance which due to its compressibility is not positive and hence creates errors.

Air is used to a great extent. It is available everywhere, it costs comparatively little, it can be exhausted to atmosphere, and hence creates no disposal problem (return piping) but it requires oiling, and its action is elastic the same as steam, because of its gaseous nature which causes it to expand with pressure changes.

Water being a liquid, cheap and available everywhere, is a handy auxiliary power medium. Its action is positive as it is incompressible. Its use requires lubrication and special non-rusting materials. Disposal piping is required. Furthermore, water deposits salts, etc., even when distillate is used. Valves are often encrusted with foreign matter, which is most annoying and impairs the reliability of operation.

Oil is the ideal fluid power medium. It is a liquid, incompressible, self-lubricating, non-rusting. It requires drainage piping. Usually the oil is used over again in a circulating system. When properly installed in a pressure-tight pipe system, oil offers the most reliable source of fluid relay energy.

Electricity is used in the form of direct or alternating current, of a voltage around 120 or 230-250. Direct current is most commonly used, although A.C. 60 cycle installations are also in use. Electricity is handy, clean, not bound to fixed locations and appears to have all advantages with no drawbacks at all.

Behind the electrical devices is the research of well organized large corporations, and the all-pervading advertising of a powerful industry with a systematic educational campaign.

Behind the fluid devices is nothing except cold, old facts that look dusty, having neither the lure of novelty nor the sleekness of appearance.

The relay of power demands either a **pilot-valve** and **power cylinder with piston,** or a **contactor** with **servo-motor,** depending on the kind of medium. The characteristics of this apparatus will be compared later.

Dynamic Nature of Process

The regulator itself is a dynamic machine which has to cooperate with the corrective device to restore the balance at point of control A.

Regulators first of all are dynamic devices—meaning they are in motion all the time. They balance definite forces governing equilibrium or movement, as the case may be.

Regulators are more than kinematic paraphernalia usually described as follows: "Where this part moves, it causes that to move also, then this goes that way and there you are."

As you all know, Dynamics is the study of mechanics treating the motion of bodies (kinematics) and the action of forces in producing or changing these motions (kinetics). Therefore, the analysis of a regulator is not a mere diagram of levers, displacements and movements. A regulator rather presents a picture of a quivering machine in constant activity, wherein several forces are constantly compared in their values and effects, now creating movement, and then equilibrium, trying always to satisfy the demands of its settings by accurately actuating the corrective devices.

The most commonly used regulator is the Flyball type speed governor of engines. They convey dramatically the idea of continued motion—up-down. Anyone who has worked on these devices trying to adjust their operation gets a full realization of the difference between motion-study as limited to the properties of space and dynamic study, which includes the action of forces, the influence of speed, the value of acceleration and the disturbing effects of inertia.

It is extremely difficult to convey this point to the engineering public, as most engineers interested have no phyiscal contact with the problems. Draftsmen, patent specialists, paper engineers, designers, etc., are usually remote from the dynamics of the job. The kinematic aspect of the problem predominates in their minds as the only visible one, while the kinetic aspects elusive, often hazy are often misunderstood, most times not appreciated at all, or neglected in their real value.

This is the reason for so many failures of perfectly reasonable looking devices once they are applied to the actual conditions in the field. Most books on the subject of regulation do not emphasize this point of dynamics. They usually are wordy descriptions of devices that confuse the student more than ever. The unquestioned ingenuity of the many kinematic devices amazes the investigator, who becomes lost in details and misses the true perspective of the problem.

Co-operation Between Regulator and Corrective Device Essential

The second feature is this: In itself the regulator is useless, of no value. A controller becomes important only in co-operation with the corrective device because its only aim is to change the settings of the corrective device, to restore the desired effect at A. The effects of the dampers on the flow have

to counteract the disturbing influences at the control point.

It follows therefore that the natural characteristics of the corrective devices have an important bearing on the practical development of the regulator itself. In fact, the influence of the nature of the corrective device is dominant, if best results are to be secured with the simplest means. A study of the inherent behavior of corrective devices must of necessity precede any detailed study of the actual regulators.

Corrective Devices Used in the Art of Regulation

Corrective devices used in the art of regulation can be classified as follows:

Fluid or Hydraulic	**A**—Valves	needle type basket type turbine type bleed type
	B—Dampers	blade type butterfly type louvre type
Electrical	**C**—Rheostats	drum type face plate type step type
Mechanical	**D**—Brakes and Clutches	

A. Regulating Valves have definite lifts, greater than the usual globe valves; they must have a definite lift-area characteristic and their size must be chosen carefully to be effective. The lifts vary from fractions of an inch to three or four inches at the utmost, depending largely on the size of the valve. The speed with which the valve stem moves is slow —something around one inch per second. If well designed, regulating valves offer an infinite number of positions between tight-shut and full-open positions and their effect is very gradual. They are used with gases, air, steam, water or oil in all kinds of industrial applications and they are built for pressures up to thousands of pounds. (See Fig. 5).

The range of their operation is very large, usually 8 or 10 to 1. Regulating valves do not, as a rule, shut off tight and should not be used as cut-off valves unless specially designed for that purpose.

B. Regulating Dampers are built for large pipe and ducts of larger size which make the application of valves impractical. They are used for any power medium such as gas, air, steam, oil and water up to 250-350 lbs.; their dimensions are sometimes unusually large especially in boilers, air ducts, etc.

They are built with one blade or multiple blades. Blades rotate either 90 degree from closed to open position, or sometimes 70-60 degree, depending on design. The bearings of regulating dampers should be of high grade construction to assure lubrication and wear and to give reliable and continuous service. The blades are moved either by outside levers or by combination rack and pinion fastened to the shaft that carries the blade. The stroke is definitely fixed and the speed of operation is always slow and very small for heavy designs. At 6″ radius not over 1 to 2 inches per second or less is admissible. Dampers have a stepless characteristic between full-open and closed positions. Their control range is large about 10 to 1 similar to the valves. Dampers unless specially designed do not shut off tight and should not be used for cut-off purposes. (See Fig. 6).

C. Rheostats are in reality electric valves; they change the resistance to the flow of electrical current just as valves oppose resistances to the flow of mechanical media. The variations in electrical resistances is done by adding or subtracting grids. Most rheostats have a definite step-action and have definite points (6-13-19-33 or more). These steps determine the range of control, 4 to 1 is common for D.C. rheostats and 2 to 1 is customary for A.C. controllers. Regulating rheostats are often combined with starting rheostats. Rheostats should not be used for shut-off purposes.

Most of the commercial rheostats or controllers do not have a definite position—current characteristics. If definite relationship is desired, calibration is necessary which more than doubles the price of the standard equipment. From the operating standpoint, rheostats are purely mechanical devices; drums or levers that have to be shifted or rotated depending on construction. Their speed of operation is necessarily slow; at 6 inch radius; about 1-2 inches per second or less. Most rheostats have definite notching devices which emphasize their step action. See (Fig. 7).

D. Solenoids are wire coils mostly of cylindrical shape that cause iron cores to move according to the energizing current. The electrical currents control definitely the direction of motion of the core and exert a definite pull but they do not control the magnitude of the motion of the core. The magnetic reaction created by the current flowing through the windings pulls in the core to the neutral position but this movement must be qualified by springs or extraneous mechanical forces opposing this motion. See Fig. 8. The grip varies with the current but the distance of travel does not. This basic feature limits the usefulness of solenoids as regulating devices but it makes the solenoids extremely practical for cut-in or cut-out devices, meaning regulating devices with only two positions. Most remote relays are based on the solenoid principle and the majority of the electrical controlled devices use solenoids in a very prolific way.

The displacements of the metallic cores are very small; they vary from fractions of an inch and seldom approach 1-inch. If large strokes are required, the original motion is magnified by toggles, levers, cams, etc. The speed of operation of solenoids seems instantaneous mostly on account of the short travel of the core; in reality the speed seldom exceed 1-inch per second.

E. Brakes and Clutches are mechanical devices that increase or decrease the flow of mechanical energy from a driving shaft to a driven shaft. They have to be used in combination because they are one-way devices.

The construction of brakes has been remarkably improved during the past ten years and their operation has been very reliable. Everybody is familiar with Crane brakes, motor-car brakes, etc. on account of the inevitable wear of the brake shoes or brake bands periodic adjustments and inspection is neces-

sary. The operation of brakes is based on short stroke movements of the controlling device. Special levers, mechanical amplifiers, hydraulic cylinders and electric solenoids are used to operate brakes depending on the nature of the application.

Clutches are mechanical devices that increase the flow of energy from one shaft to another. During the past ten years their construction has been highly perfected. Automobile designs contributed a lot to research investigations with regard to brakes and clutches as well as many industries with selective mechanisms such as type-setters, etc. are based on quick acting clutches and brakes. The operation of these machines seems fast and quick as lightning to the onlooker but the speeds and action of the clutches are very reasonable because the movements involved are only fractions of an inch.

Brakes and clutches are sometimes used for regulating purpose and their combination offers definite possibilities especially in their modern designs. Very smooth and even stepless action can be obtained by the ingenious development of this combination, over large ranges of operation.

Before deciding on how the above directing devices can be best operated either by mechanical means, by fluid means or by electrical means, it is necessary to study the characteristics of the available amplifying devices of this media.

Characteristics of Fluid Amplifying Devices

Amplifying devices are used to change a small impulse (movement, force or moment) into a large one. Hydraulic amplifiers do this by means of a combination of pilot valve and power cylinder with piston.

Hydraulic pilot valves release oil, water, air, or steam under pressure by moving a small piston along ports. They have small strokes usually less than one inch and are completely balanced to require very little force for operation. Pilot valves have an infinite number of positions between full-open one way, neutral and full-open the other way.

The power released by the pilot valve goes to one side or the other of the double acting piston moving in a cylinder positively connected with the correcting device. To assure proper operation the motion of the pilot valve and power piston must be compensated. The combination pilot valve and power cylinder permits enormous amplifications sometimes as high as 1,000 to 1. Their operation if properly designed is not only smooth but powerful and highly accurate. Pistons usually have short strokes and this feature makes them very adaptable to the construction of valves, dampers, rheostats, brakes and clutches which have the same characteristics. The power device harmonizes with the device to be operated. All operations start, stop, reversals can be handled swiftly and smoothly without noise or lost motion. Limits are naturally provided by the cylinder heads and direct connection is possible without intermediate equipment. (See Figs. 9, 10 and 11).

The drawbacks of fluid amplifying devices, based on pilot valves and power cylinders, are basically their limitations as to space. The pilot valves must be located within reasonable distance from the power cylinders; not over 100 ft. or thereabout. That feature makes remote control practically impossible, and limits the flexibility of the device. Minor drawbacks are clumsiness of appearance and necessities of piping and linkage.

Characteristics of Electric Amplifying Devices

Electric amplifying devices use a combination of contactors (switches) and electric actuators. The electric contactor releases the flow of the electric current and requires very little force for operation and small motions. The current released feeds an electric motor or a solenoid directly connected to the corrective devices used for regulation.

Electric contactors are essentially three-position devices full one way, neutral and full the other way. They do not permit intermediate positions or shading of the power released similar to pilot valve with their gradual opening of ports. This fact is a distinct drawback of electrical amplifying devices and complicates their application for regulating purposes. (See Fig. 12).

Electrical actuators are usually motors A.C. or D.C. receiving their impulses from push buttons or automatic electric contactors. These motors have always a rotary movement and by nature have a high speed and a low torque. To operate valves, dampers, rheostats, etc., they must be connected by means of reduction gears because the high speeds of the power device has to be modified to correspond to the low speed of the correcting devices. Furthermore, limit switches must be provided to determine the end positions and brakes must be provided to reduce quickly the influence of the rotating masses and inertia effects.

There is no basic correlation between position of contactors and position of the rotor of the actuator. No compensation device of the motion has been developed so far, which makes motion control difficult.

Electricity being a massless form of energy no corresponding reactions can be developed to take care of velocity changes, acceleration effects of moving bodies. This is inherent.

Electrical amplifying devices have the natural advantage of flexibility and independence of location and space. They are ideal for remote operation of small massless devices, such as radio, light, and sound, or kindred application. For operation of correcting devices demanding heavy forces, and quick response, special compensating apparatus and devices have to be interpolated between contactor and actuator to take care of the inertia components and time delay reactions. These devices usually take the form of periodic interruptors which have definite characteristics and are far from being fully developed and universally adaptable to all applications.

It is hoped that the above outline gives a firm foundation upon which studies can be based to compare the adaptability of fluid regulating devices and electric regulating devices. It is very difficult to draw positive conclusions as we have limited ourselves so far only to the kinematic features without detail analysis of the dynamic features.

Combustion Control for the Open Hearth Furnace*

By P. S. DICKEY†

The Operating Problem

The past few years have seen a very decided awakening of interest along the line of improvement in the efficiency of the open hearth process. This is the natural outcome of an industrial age in which there is always pressure present towards carrying any product from its rough to finished state with a minimum cost. As in the generation of power, the cost of purification of steel is a function of the utilization of natural resources more than of the manpower involved, and any improvement in the process must, therefore, be in the direction of conservation of these resources.

To obtain improvement in the efficiency of the process as well as quality of the product, we naturally turn towards devices which will indicate the operating efficiency, and from those to devices which will automatically control the process to maintain that operating efficiency. There is, however, considerable difference of opinion as to just what metering and control devices will make sufficient improvement in the operating efficiency of the open hearth process to justify their installation.

The two items of cost which show greatest possibilities of reduction are those of fuel and of refractory maintenance. A small percentage saving in either of these items will justify a surprisingly large investment of capital for metering and control equipment to effect such saving. Let us discuss these two possibilities. With the interest now being shown towards improvement of the open hearth process and with the advent of measuring devices for telling us more about this rather involved process, there is little doubt that other control mechanisms will prove themselves justifiable.

Combustion Efficiency

It is not the intent of this paper to go into any technical discussion of the combustion process. Although the open hearth furnace is in a class by itself, there are a few principles of combustion which apply here as well as elsewhere.

In the chemical combination of oxygen with fuel of any kind, there is a definite heat release, depending upon the chemical analysis of the fuel. With this release of heat energy the products of the oxidation process are raised in temperature, the amount of increase in temperature depending upon their specific heat and quantity, and upon the heat loss by radiation, conduction and convection to surrounding bodies.

Fig. 1 shows the theoretical temperatures developed by the combustion of hydrogen and carbon, which are the principal useful constituents of any fuel. These curves are based on the fuel and air supply entering the combustion process at ordinary atmospheric temperatures. Since the air supply in the case of combustion of carbon to carbon dioxide is somewhat over eleven times the carbon in weights, and in the case of hydrogen somewhat over thirty-four times the hydrogen weights, it is evident that if the air supply enters the process at a temperature of 1000° F. or more, as is the case in the open hearth process, the theoretical temperatures developed would be considerably higher.

In the open hearth process, we are interested in transferring a maximum amount of heat to the bath with a minimum expenditure of fuel supply. Since the heat transfer of the open hearth is almost entirely by radiation, and since radiant heat transfer is a function of the fourth power of the absolute temperature differences, Fig. 1 shows why the natural tendency is for the operator to regulate heat transfer with the air supply, with no consideration of the effect of excess air upon the efficiency of combustion.

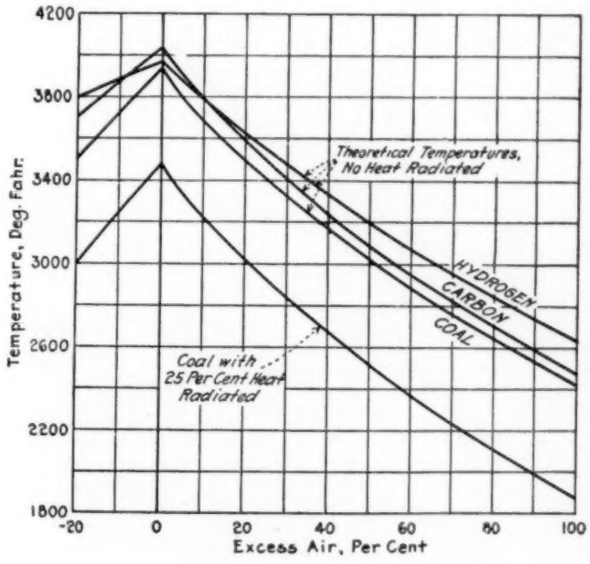


FIG. 1.

The theoretical temperatures shown in Fig. 1 are unattainable without preheated air or fuel, since it is evident that a furnace in which there is no heat transfer to the surrounding bodies is unattainable. In the ordinary open hearth furnace the temperatures developed are considerably lower than the theoretical temperatures with the same excess air due to the large amount of heat transfer to the surrounding bodies. However, the trend of temperatures developed with varying percentages of excess air is exactly the same. In view of the fact that for a given furnace the radiant heat transfer will be reasonably consistent for a given temperature difference, it is evident that furnace temperature may be maintained either through the combustion of large quantities of

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† Bailey Meter Company, Cleveland, Ohio.

fuel with high percentages excess air, or with relatively small quantities of fuel with a low percentage excess air. A study of the effect of improper air regulation upon the efficiency of the process will show that furnace temperatures for different rates of heat transfer must be obtained through regulation of the heat input, with the air supply controlled to maintain the desired excess for efficient combustion of the fuel. Maximum thermal efficiency can only be obtained by minimizing the following losses:

1. Loss due to temperature of the products of combustion at the stack.
2. Loss due to unburned fuel.
3. Loss by radiation to surrounding bodies.

When a given furnace temperature is maintained by combustion of large quantities of fuel with more than the amount of air required for complete combustion, heat is lost due to an increased quantity of products of combustion leaving the furnace at an increased temperature. While a portion of this heat loss is recovered in the checkers and in other heat recovery devices, the flue gas loss is still high, due to the final flue gas temperature. Fig. 2 shows the percentage of heat loss with varying quantities of excess air in an average open hearth furnace equipped with a waste heat boiler. It will be seen that with 200% total air, almost 30% of the fuel burned is used in heating air which does not enter the combustion process and therefore represents an absolute loss. This percentage heat loss is based on a furnace equipped with a waste heat boiler which permits reduction of the stack temperature to that shown. The loss will be proportionately higher from furnaces not equipped with waste heat boilers, in view of the higher stack temperature.

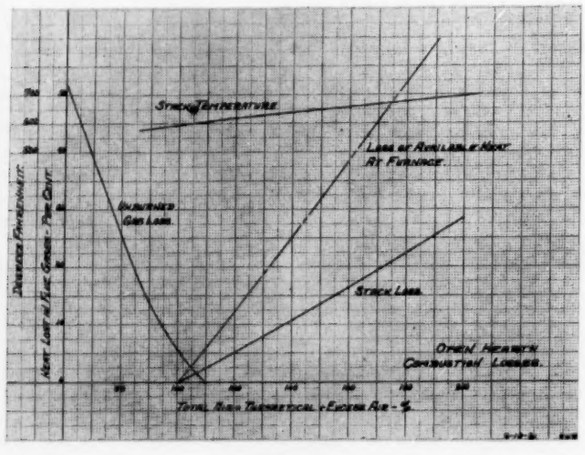
Stack Temperature
Loss of Available Heat At Furnace
Unburned Gas Loss
Stack Loss
Open Hearth Combustion Losses
Total Air Theoretical + Excess Air - %

FIG. 2.

A second, somewhat intangible loss is experienced with combustion of the fuel with more than the required amount of air. If a large portion of the heat released by the combustion process is used in raising air which does not enter the combustion process, to the furnace temperature, it is evident that the furnace temperatures available will be reduced. While this does not represent a direct thermal loss, since the heat is recovered in the checkers, it must be considered since with the lower furnace temperature the rate of heat transfer is reduced and the time of the heat is lengthened.

Fig. 2 also shows the heat loss due to the unburned fuel, and it is apparent that this loss is equally as serious as the excess air loss. The curve shows that the most desirable point from the standpoint of efficiency is that of combustion of the fuel with from 5 to 10% excess air. A deficiency of air in addition to decreasing the combustion efficiency, may result in secondary combustion in the checker work, with increased deterioration at this point. At certain stages of the purification process, quantities of carbon monoxide are developed from the bath, and at this time it is necessary to supply an excess of air over that required to properly burn the fuel to take care of the combustion of this carbon monoxide.

Radiation losses are primarily a function of hearth design. A good many studies have been made to secure a design which will hold this radiation loss to a minimum. The only controllable factor is that of furnace temperature, and since the time required for heat is important, furnace temperatures must be carried high to secure sufficient heat transfer. However, there are periods throughout the process where a high rate of heat transfer is not so essential and a reduction of furnace temperature at this time will help towards a reduction in radiation losses.

For efficient combustion of the fuel it is seen that there is one comparatively narrow range of excess air to be supplied. It is the writer's impression that past practice has been to design a given open hearth furnace for combustion of fuel at a certain rate and operate the combustion system almost entirely at that rate. To obtain the different transfer rates necessary for the "melting down" and "working" periods, the operator varies the furnace temperature by means of different quantities of excess air, with a resulting drop in efficiency. A material improvement in combustion efficiency should be possible by controlling the air supply to maintain the proper excess at all times, and by regulating the furnace temperature by means of the quantity of fuel burned. Adequate metering and control devices will show this to be entirely possible, and a material saving in fuel will be effected. In any case, when we consider the fact that only 15 to 20% of the total heat required is used in bringing the bath to the working and pouring temperature, it would seem that there is room for improvement in the efficiency of the process.

Refractory Maintenance

In improving the economic efficiency of the open hearth process, the reduction of refractory maintenance is equally as important as the reduction of the fuel burned. While refractory maintenance, as is the case with radiation loss, is largely dependent upon design of the hearth and proper selection of refractory materials, it is also dependent upon proper control of furnace temperatures and reduction of flame impingement. Refractory materials are generally not capable of withstanding rapid temperature changes and if furnace temperature control is obtained through regulation of the quantity of fuel burned rather than by variation of the excess air content, the temperature changes will be slower and the strain on the refractories less severe. Proper regulation of the fuel—air relation will improve burner efficiency and there will be less tendency towards flame im-

pingement which is highly instrumental towards refractory failures.

Accurate control and indication of the draft or pressure within the furnace is highly desirable, both from the standpoint of reduction of refractory maintenance and efficient combustion of the fuel. While the modern furnaces are being built with more careful attention towards reduction of the infiltration of air, the very nature of the open hearth furnace makes it difficult to obtain an air-tight construction, and it is therefore essential that the furnace pressure be maintained within a narrow range which is close to atmospheric pressure. A high furnace draft will cause considerable infiltration of air, and as this air enters at a point where it most likely will not enter the combustion process, it represents a loss even greater in percentage than the excess air loss shown in Fig. 2, since it enters the furnace at atmospheric temperature instead of some 1600° F. which is the temperature of the combustion air leaving the checkers. In order to reduce this infiltration loss, the draft is maintained close to atmospheric pressure, and there is a possibility that disturbances may create a pressure within the furnace, if careful control is not provided.

There has been considerable discussion as to where any indication of furnace draft for operating or control purposes should be obtained, since with the chimney action effect due to the large temperature difference between the inside of the furnace and the atmosphere surrounding, different pressures exist at different elevations within the furnace. Higher drafts are always experienced at lower elevations, and in view of this fact certain operators believe that the furnace draft connection should be made at the roof, since it is at this point that a pressure is most likely to develop. Other operators state that the relation between drafts at different elevations will not vary greatly, and in view of their experiences with slag formation at the roof, believe that satisfactory operation is more likely to be obtained if the furnace draft connection is taken at the side of the furnace about the elevation of the charging doors, with the draft at this point carried which will not permit a pressure to develop at the roof of the furnace.

Means should be provided for rapid and accurate control of the relation between forced and induced draft supply so that the furnace draft may be maintained within close limits, if flame impingement and refractory troubles are to be minimized. If automatic control of the air supply in relation to the fuel is to be used, it will be desirable from the standpoint of proper furnace draft control, when making a change in the air supply, to make this change by parallel changes in the forced draft and induced draft supply, with the induced draft leading slightly on the increase and lagging slightly on the decrease, so that the variation in furnace draft with the change in air supply will not be great but will always be towards the draft side.

The present method of reversal of the furnace offers room for improvement since a more uniform furnace condition would result if instead of having all the reversal valves operate simultaneously, the reversal were worked out on a sequence basis, and carefully timed so that a slight draft would be maintained in the furnace during this period.

Automatic Control Equipment

Organization

In the foregoing part of this paper, it was pointed out that a considerable expenditure of capital is warranted for metering and control equipment to improve the combustion efficiency and to reduce refractory maintenance of the open hearth furnace. In designing a control system to handle the open hearth problem, it is well to keep in mind the three fundamental characteristics of any control system, which may be listed as follows:

1. Accurate and reliable metering equipment
2. Centralization and flexibility of the control equipment
3. Adequate records of operation.

A properly designed control system is quite comparable to a smooth working manufacturing organization. In the manufacturing organization, the first requisite for efficient operation is a foreman who might be defined as a device for determining the satisfactory performance of any process. If the foreman cannot accurately and continually visualize conditions in his process, he cannot maintain smooth and efficient working in his department. Likewise, in working up the automatically controlled system, the most important job of the control manufacturer is to get positively accurate measuring devices to show continuously the conditions to be maintained. As your production of steel with efficiency depends upon your ability to select foremen who can keep the various departments functioning properly, so our reputation as control manufacturers depends more than any other thing upon the selection and development of devices for indicating the various conditions of the many different types of processes which are automatically controlled. The best workmen and likewise the best control mechanisms will fail to produce results if short sighted and flighty foremen and if inaccurate and unreliable measuring devices are used.

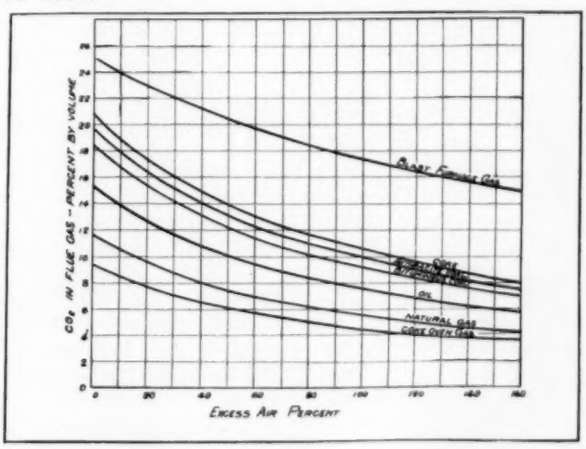

FIG. 3.

For the remaining part of our manufacturing or our automatic control organization, since there is mechanical work to be accomplished, men must be selected who are capable of performing the functions demanded by the foremen without fatigue, and so must control power devices be selected which will carry out the demands of the measuring devices without failure. The demands upon this part of the organization, however, are not so great but that a

somewhat greater latitude may be used in selecting the type of workmen or power mechanisms with equally good results. The principal point to keep in mind is that proper regulations and limits for these power devices must be provided so that no matter how badly they fail in performance, they cannot do damage to the devices that are being controlled. Proper interlocking between the different mechanisms must be worked out so that trouble with any one mechanism will not in any way permit that or any other to cause damage to the entire system.

Likewise, of utmost importance in the development of a control system or of a manufacturing organization is the centralization of the organization and the records of performance which it keeps. For example, in the manufacturing organization the foreman must be in immediate contact with all of his men and must keep adequate records of the performance of his department. In the automatic control system this centralization is obtained by grouping all metering devices and remote controls for starting, stopping, and changing the sequence of operations on a central board where the operator has immediate control of every function. The control system should be arranged so that every measuring device which serves any important control function is of the recording type, so that it reports to the operator not only instantaneous conditions but the trend of conditions, and when any unusual operation occurs which may otherwise escape the operator's attention. It does not require further amplification to point out the benefit of such organization over that of a number of independent control mechanisms with no coordination, plugging away—from all external appearances very busy—but keeping no record of what is being accomplished.

Metering Equipment

A great many kinds and varieties of metering equipment are available for the open hearth process. For a complete picture of the process, it is desirable to have indications of drafts or pressures at various points within the furnace and flues, with a record of the draft within the furnace. Temperatures at various points in the gas and air passages show the effectiveness of heat transfer and the magnitude of the combustion losses. A metered record of every fuel burned will serve not only as a check on the overall heat consumption but for the heat consumption at various stages of the process. For regulation of the air supply, it is necessary that a metered record of the fuel supply and the air supply be available, and it is recommended that this meter be of the "relation" type so that all the operator or control mechanism has to do is to maintain a definite relation between the fuel and air supply for maximum efficiency.

The combustion process in the open hearth furnace is considerably complicated due in many instances to the different fuels which are burned. Determination of the excess air supply is not possible by analysis of the products of combustion, as is shown in curves of Fig. 3. From these curves it will be seen that for 20% excess air, the carbon dioxide content of the flue gas varies from less than 8% with coke oven gas to more than 22% with blast furnace gas. However, for a wide range of types of fuel, the heat released in B.t.u. per pound of air required for combustion is reasonably constant. If the metering equipment is arranged to meter each fuel individually and record in terms of

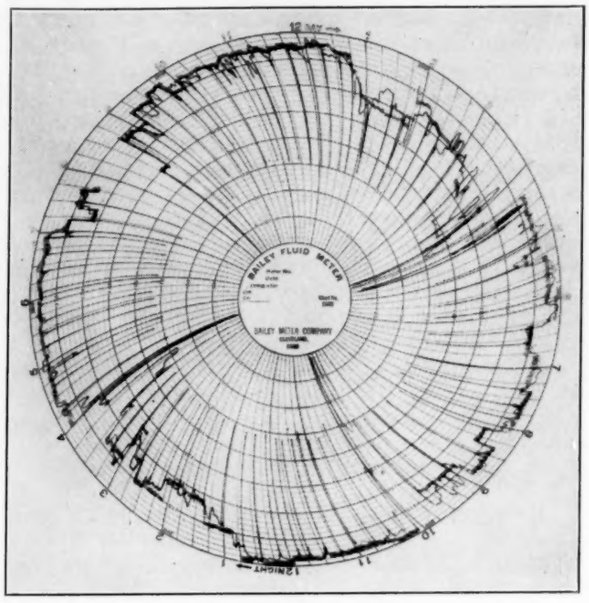

FIG. 4.

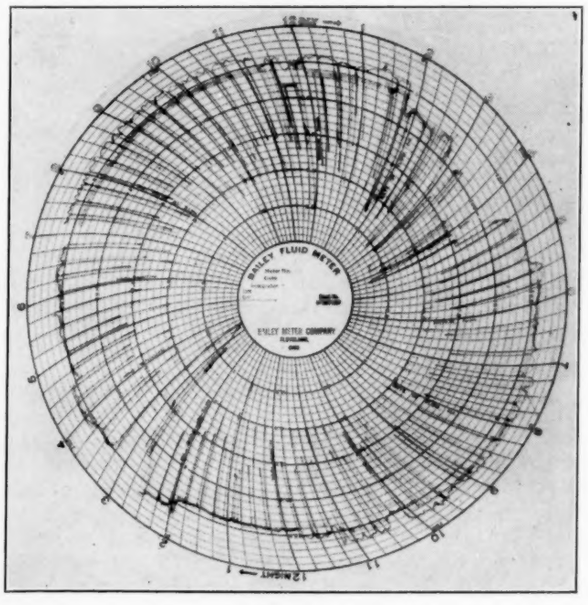

FIG. 5.

pounds or cubic feet, depending upon the fuel, and in addition, all fuels are totalized on a B.t.u. basis on a separate meter chart so that a combined record of B.t.u. supply and air required for combustion is obtained, a relation may be established between these two so that the operator can maintain the desired excess air with a minimum of difficulty regardless of the ratio of fuels burned. Certain fuels such as blast furnace gas will not give the same B.t.u. release per pound of combustion air as the ordinary open hearth fuels, but it is comparatively

simple to arrange the metering equipment so that the air flow record is compensated in proportion to the amount of blast furnace gas which would be burned. The B.t.u. flow—air flow relation will then be correct regardless of the fuel being burned.

Since we are interested only in the air supply from the standpoint of efficient combustion, it is still further desirable to arrange this B.t.u. flow—air flow meter so that the desired excess air is maintained when the two records have a unity relation. The proper excess air for efficient combustion will then be maintained either automatically or manually at all rates of flow with a minimum of difficulty. Figs. 4 and 5 show chart records from a relation recording meter applied to open hearth combustion work. These two meters happen to be installed on furnaces fired with single fuels so that the records are of oil flow and air flow, although the same type of record would be obtained with a B.t.u. flow—air flow meter. The reversals of the furnace are clearly shown on these records, and the second record shows operation with a small percentage of excess air being supplied, probably to take care of the CO generation from the bath.

A typical metering layout for a furnace fired by a single fuel is shown in the diagrammatic layout on Fig. 6. The metering equipment consists of the oil flow—air flow relation recorder and the furnace draft recorder in the center of the board with recorders showing the temperature at various points in the gas passage on either side, and an indicating gage for drafts and pressures at the top of the board.

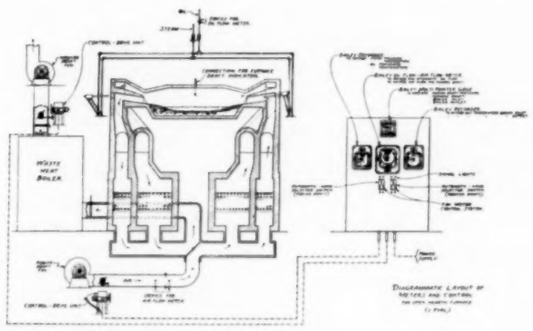

FIG. 6.

A typical layout of metering equipment for a furnace fired by several fuels is shown on Fig. 7. The righthand meter records gas flow and gas pressure, and the lefthand meter B.t.u. flow and air flow, and furnace draft. The B.t.u. flow represents that of the gas and of the tar or oil. The indicating gage shows drafts and pressures and temperature recorders may be added to the panel if desired.

With automatic control equipment, the control is arranged to maintain the unity relation between the B.t.u. flow and air flow, and adjustment is provided so that the quantity of excess air may be varied at different phases of the heat if desired. For the control of furnace draft the control mechanism may be operated from the recording device of the meter or from a separate indicating device. The record will show any improper operation of the control and will likewise show if any unusual furnace conditions develop.

Control Mechanism

Control mechanisms for open hearth work may be either hydraulically operated, a combination of electric and hydraulic, fully electric, or air operated. Each system has certain advantages and in certain cases a given type of equipment is most satisfactory for the operating conditions. However, with the thousands of mechanisms which have been developed for control work, each control system is basically the same and consists essentially of two parts; first, a selector mechanism which is actuated by a meter or indicating device and which will be of one of two types, depending upon the storage of energy within the system under control. One is of the "geared" type and will make its changes in a direction and of a magnitude depending upon the rate of change of the indication being controlled, and is applicable to a system where there is a considerable storage of energy involved. The second is of the "floating" type and will make its correction in a direction and of a magnitude proportional to the amount the indication is away from the desired condition. This second type is used with a system where there is very little storage of energy and the reaction of the system is complete and instantaneous. The second fundamental part of any control system consists of a power device and it may be a diaphragm motor, a hydraulically operated piston, a reversing pilot motor, a continuously running pilot motor with mechanical clutches, or any of a number of other different power devices. Most any of these, if properly designed, will give satisfactory performance.

Generally speaking, the following may be said of the different types of control mechanisms:

Hydraulically operated control will give excellent service with low maintenance cost, if oil is used as the actuating fluid. A properly designed hydraulic system which gives the desired flexibility of operation and which provides satisfactory protection to the devices being controlled and interlocking and protection against runaway or other unusual conditions will be more expensive than an equivalent electrical system. Oil operated systems are not suitable where the indicating devices and power devices are separated by considerable distance, and where facilities for running pipe lines are inadequate.

A high degree of precision and a wide range of control speeds is available with oil operated hydraulic control if the pilot valves are properly designed, with due consideration of the power available at the indicating device and if the valve is balanced and is kept free by rotation.

Air operated control systems are probably the lowest cost control systems where a supply of compressed air is available in the plant. The air operated system is likewise capable of giving good sensitivity and control speed range, since the air operated pilot valves are well adapted to use with indicating devices of low torque. However, since it is practically impossible to obtain a clean and dry air supply, the air operated system requires more maintenance than other types of control apparatus. The air operated system is even less satisfactory than the oil operated system where the indicating power devices are separated by some considerable distance.

A combined hydraulic and electric system is available, wherein the transmission of indication is obtained entirely by electrical means with the torque

amplification and selectivity of movement being done hydraulically. This system offers the ease of installation and of indication transition of the electrical system with the smooth performance of the oil operated hydraulic system. The cost of this system is comparable to that of the oil operated hydraulic system when satisfactory flexibility of operation and protection is provided with both systems.

The electrically operated control system offers a high degree of flexibility of operation without complication of the control apparatus, and it is particularly well adapted to installations where the indicating devices and the power devices are separated by some distance, since electrical wiring can be installed under most any conditions without very much difficulty and at a very reasonable cost.

Electrical control has the further advantage that it is equipment with which the maintenance force in the average plant are familiar. The same accuracy of control and range of control speeds is available with electrical control, although care must be exercised in the design of the contacting and power units if the accuracy and speed range is to be obtained without a sacrifice of operating life of the apparatus. Electrical control generally ties in with the plant equipment most easily, since ordinarily most of the auxiliary equipment is electrically operated.

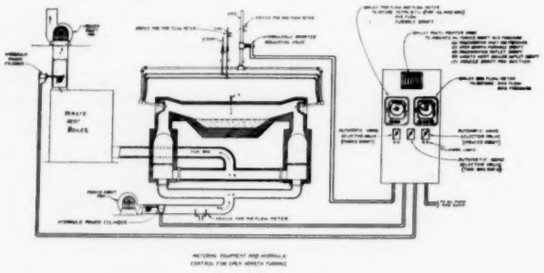

FIG. 7.

However, plant conditions often make one or the other type of control mechanism most desirable, and it behooves every manufacturer to have available more than one type of control equipment. Insofar as the general problem is concerned, the type of control equipment is of no concern, since it is only a question of comparing one mechanism against the other. The principal points to keep in mind in working up a control system for open hearth work is to be sure that the metering devices are reliable, that the basic principle of the control scheme is sound, that the control system is centralized and is flexible enough for the purpose, and that adequate records of operation are kept.

Fig. 6 shows diagrammatically the layout of control equipment for maintaining the combustion efficiency and furnace draft of an open hearth furnace. It will be seen from this drawing that the control and metering equipment are centralized at the panel so that the operator has a complete picture of operation, and has control of each factor from this panel board.

Fig. 7 shows the layout of an oil operated hydraulic system for open hearth control. This layout in addition to providing for control of the fuel flow —air flow relation and furnace draft, provides a ratio control between gas and tar to provide a fixed relation between the quantities of the different fuels burned. The same flexibility of automatic or hand operation of the various factors is included with this hydraulic system by means of the selector valve on the panel board, and the control and metering equipment is grouped so that the operator has a complete picture of operation and control of the different factors from the panel board.

Future Possibilities and Conclusions

We believe that the future holds in store a development of automatic furnace temperature control so that the desired temperatures in the furnace, and perhaps of the bath, will be maintained at different stages of the heat. However, there is not available at this time a temperature device which is accurate enough and reliable enough to even consider a control of this nature. If such a temperature indicator is made and it is developed into a recording instrument, we believe, however, that the desirability of automatic control would immediately be shown.

We believe further experience with automatic control equipment will show the desirability of automatic reversal of the furnace. Whether or not this reversal should be accomplished on a time or a temperature basis, or perhaps a combination of both, we can only guess. Any control of reversal must, of necessity, be extremely flexible due to the varied conditions arising.

However, for the present we are primarily concerned with the conservation of fuel and the reduction of refractory maintenance. We believe that very material savings in fuel costs and in refractory maintenance costs are possible through the installation of adequate metering and control devices which will maintain the desired excess air supply for combustion and which will maintain within close limits the pressure within the furnace. We further believe that with the advent of proper metering equipment giving a more complete picture of the open hearth process, there will come still more automatic control equipment to improve the process. The Bailey Meter Company is anxious to co-operate with the operators of open hearth equipment, and believes that with proper co-operation between the open hearth users and manufacturers of metering and control equipment, great strides will be made toward improvement of the economic efficiency of the process and perhaps even in the quality of the product.

Combustion Control*

By GEO. D. CONLEE†

The announced topic for this meeting: "Mechanical vs. Electrical Devices in Connection with Combustion Control Apparatus" is very comprehensive, in fact, much too broad for treatment in a single paper or at a single meeting. It seems that a short consideration of the whole combustion control field will be helpful. The combustion process is used in various ways in the steel mills, and the many applications are radically different, both in method and object to be obtained, so that each must be studied carefully if any real progress is to be made. The combustion of coal under a steam boiler is radically different from the combustion of coal in a gas producer, or the combustion of gas in an open hearth furnace.

The combustion of coal or other fuel for the generation of steam in a boiler furnace is controlled with just one object in view; that is, the production of a volume of gases at the highest possible temperature. The modern boiler has much water cooled surface looking at the flame, all water cooled surface is substantially black body when considering the absorption of radiant heat, and as the rate of heat transfer is as the fourth power of the temperature difference between the flame temperature and the water cooled surface, obviously the higher the flame temperature, the more radiant heat there will be absorbed and the better the boiler efficiency. If it were possible to obtain complete combustion with only the theoretical amount of air, the maximum efficiency could be obtained. Actually somewhat more than the theoretical amount of air is required and the whole object of automatic control is to maintain the excess air supplied at a minimum compatible with complete combustion. The fuel supply is controlled by the steam pressure and then the air supply controlled to maintain the best combustion efficiency possible. In other words, the whole object in view is to balance the fuel supply with the steam demand and then supply just enough air for the highest combustion efficiency.

In the case of an open hearth furnace, not only is the fuel different, but the results striven for are different. The combustion must be maintained with the products of combustion either oxidizing, reducing or neutral, as the particular process may demand. Again, control of an open hearth furnace is entirely different in principle and operation from the control of a furnace where there is no reversal of flow. The control problem is further complicated by the fact that open hearth furnaces are far from air tight and the amount of air leakage along the path of the gases is uncertain and varies from day to day.

I don't want to detract from the wonderful results obtained by the application of automatic control to the operation of boilers, but I do believe that control of the open hearth furnace is a much more difficult problem and one that will require much study and experience before the problem is solved.

At the present time there is much interest in automatic control of open hearth furnaces, and there are several systems on the market that appear to have many good points and will certainly assist in obtaining higher efficiency. The equipment has not been developed to the point where there is a unanimous opinion that automatic control is a cure-all for the operating troubles experienced in actual operation. One thing that appears to be evident is that automatic equipment will not reduce the labor required to any great extent; in fact, it is a question in my mind if the change for service and maintenance will not increase the total labor charge for heat. Consequently to show a saving there must be a reduction in time for the heat and the fuel consumption with the other rather intangible factors of better product, and possibly longer furnace life. If these facts cannot be proven, there is no argument for automatic furnace control.

An open hearth furnace is very expensive to operate and I believe it is safe to assume that the largest controllable item is for fuel. The only way to learn what is going on in a furnace is through the application of a system of instruments that will furnish the melter and the first helper with a complete story of all that is happening along the path of the gases from their entrance into the checkers until they leave at the stack. Any equipment that consumes large amounts of fuel should have automatic control, and then the control equipment should be checked by means of records of pressures, temperatures, CO_2 in the flue gases, etc. Our company has not brought out any equipment for the automatic operation of open hearth furnaces, although with our system of metering, it would be a comparatively simple adaptation of a well-known principle.

Lately I have been much interested in the problem connected with the control of open hearth furnaces, so that I am going to confine this discussion to the application of instruments for the control of this particular type of furnace. There are various kinds of data obtainable from the open hearth furnace, all of which seems to be of value for the scientific control of operation.

In my opinion the various data with their relative importance are as follows:

1—Rate of supply and the amount of fuel supplied to furnace per heat.

2—Air supply for combustion of the fuel.

3—Drafts and pressures at various points in the flues and downtakes.

4—Temperatures in the flues.

5—Composition of the exhaust flue gases.

Probably there will be some question about the relative importance of the several items, but I think there will be no question about the paramount importance of the first item. To my knowledge, there has been no attempt made to apply automatic control to this very important function. It appears that this cannot be handled automatically, because it is

* Presented before Combustion Engineering Division of A. I. & S. E. E. at Cleveland Convention, June, 1931.

† Engineer, Republic Flow Meters Co., Chicago, Ill.

the factor that must be adjusted by the first helper to suit the conditions as they exist.

Fuel Supply—Its Control and the Value of Metering

In considering the installation of meters for the measurement of both fuel and air, the question that is no doubt uppermost in the minds of those responsible for the expenditure is of what value will these be in the making of steel? The answer to this question, based upon rather wide experience, is that there is no one instrument that can installed, or in fact, no expenditure that can be made that will better furnace operation as much as the installation of indicating and recording flow meters.

Our various district engineers and service men have installed many of these meters on open hearth furnaces and, when the meters were started, invariably it was found that there was an excess of from 20% to 30% more fuel than necessary being used. We have one district office in particular where the service man always makes it a point to start the meter during the process of making a heat. This is done intentionally, with the idea of determining how much excess fuel is being used. An excess of fuel is always shown and the reason for the excess is then considered. Regardless of how luminous or non-luminous a flame may be, it is impossible for the melter or first helper to judge the rate of fuel supply close enough to be sure that the heat will come through in good shape. To use an open hearth term, the operators are not going to take any chances of having a "sticker" by cutting down the fuel supply. Because of the impossibility of judging closely, the obvious thing to do is to give the furnace all of the fuel that it can possibly take.

An indicating and recording flow meter, calibrated to read directly in units of fuel, eliminates the doubt of the first helper's mind, and he can go on about his work, knowing definitely just how much fuel is being supplied. Even with the installation of full automatic control for reversal and for control of combustion, the best possible results cannot be obtained unless the exact amount of fuel being blown, and the draft conditions in the up and down-take, are in sight of the operator at all times.

As stated above, the great value of a flow meter is in having the indicator a direct reading instrument that shows the furnace man the rate of fuel consumption in units that he will understand. The indicator must be placed in such a position that it may be seen from all points around the furnace. If the operator cannot see the instrument, or interpret the reads easily, little use will be made of them. Hence, electrically operated flow meters offer advantages.

The kind of fuel available may vary from time to time and much of the automatic equipment now on the market has to do with the proper proportioning of the air supply to the fuel supply. In order to produce a static head sufficient to allow for the necessary drop in pressure to obtain good control, blowers have been installed to supply the primary air to the checkers. This makes it possible to accurately measure the primary air supply to fit the fuel supply.

If producer gas is the fuel used, there is no direct method of measuring the gas supplied to the furnace. The amount is arrived at indirectly by measuring the air or the steam supplied to the producers. This gives a fairly accurate result which, while not as satisfactory as a direct measurement, is much better than nothing and really serves a useful purpose.

If natural gas, coke oven gas or blast furnace gas is used for fuel, the supply is always under sufficient pressure so that the actual flow can be measured by means of an orifice meter. In the case of blast furnace gas, or coke oven gas, special precautions must be taken to prevent trouble if the gas be dirty or high in moisture. The art of metering has developed to the point where these difficulties can be practically eliminated and reasonable attention to the metering equipment will insure accurate results.

With any of the gases high in hydrogen and CH_4, it is customary to burn oil or tar for the purpose of increasing the luminosity of the flame with the expectation of increasing the rate of heat transfer to the bath. It appears that there may be some question about this condition being true in all cases. A little while ago, I attended a discussion on open hearth operation, and several men claimed they were obtaining exceptionally high efficiences when burning coke oven gas without any addition of liquid fuel.

Present day furnace practice demands the simultaneous use of two, or in some cases of three, fuels. There must be some method provided for controlling the amount of fuel so that the supply will be constant at the rate at which it is adjusted.

The measurement of light oil, gravity 20° Baume or above, is comparatively simple and satisfactory results can be obtained without much difficulty. When heated sufficiently to atomize properly, the viscosity is low enough so that the orifice coefficient is not seriously affected.

The measurement of heavy oil and tar presents some difficulties, and we have found that they can best be overcome by placing the meter body as close to the orifice as possible, say within two or three feet. This makes it almost imperative to use an electrically operated meter if the readings are to be conveyed to the operating floor.

It is possible to arrange a meter so that it will be active and come to zero during the time of reversals, but the data for calculation of coefficients and the effect of viscosity is not well enough known so that an orifice can be calculated to give an accuracy within a couple of percent. The most satisfactory arrangement is to run weighed calibration tests under operating conditions on the meter periodically. As the usual demand is from 400-gallons per hour downward, this is comparatively a simple matter and will assure results that will check with tank car receipts.

The function of an oil meter on an open hearth furnace is to give an indication and record of rate of flow. Comparative accuracy is the important point, since it is used for control purposes. Absolute accuracy is of secondary importance, since small integrating meters that can be easily calibrated can be used for this service.

Meters should be installed for measuring each of the fuels used. The meters customarily consist of an indicator, a recorder and an integrator; the indicator for the convenience of the operator, the recorder for

making a record of the rate of flow, and the integrator for convenience in obtaining the total fuel charge for each heat.

In the burning of oil or tar it is customary to use steam for the atomizing agent. A steam meter with a record of steam flow, steam pressure and steam temperature is considered of importance in maintaining balanced conditions in the furnace.

Air Supply:

In order to approach efficient operation, there must be some method of measuring the amount of air supplied for the support of combustion. This is where the "joker" comes in, because there is an indefinite amount of secondary air which enters through the checker chamber walls, around the doors and in fact all along the line. This air leakage is an unknown quantity, the only definite fact being that it will increase as the furnace grows older. In the best of furnaces it is no inconsiderable amount—something in the nature of 40% or more. Tests have been made on cold furnaces but they really are of little value. Orsat determinations on hot furnaces without a charge tell a little more, but at best it is a changing condition and cannot be predicted. I have been told that it is customary in the North of France and Belgium to encase the checker chambers, and even the furnace itself, in steel sheets to keep down this leakage. Some such enclosed furnaces have been built in this country and I understand that the results have proven very satisfactory.

In this connection, the paper by Wm. H. Henry and T. J. McLoughlin before the recent meeting of the American Iron and Steel Institute is of great interest. In a well constructed furnace, it was found that only 58.2% of the air required for combustion passed through the checkers on the incoming end. The flue gas analysis showed 9.9% excess air so that only a little more than half of the air represented in the flue gases entered through the checkers, that is in the form of primary gas. If the secondary air was supplied by means of a fan, then there might be less leakage inward into the checker chamber but rather outward, because of the slight pressure produced, but even so, it appears that the question of the air leakage is one that must be seriously considered.

I do not believe that there is any method of predicting the amount of secondary air that will enter any furnace, and so the exact amount of primary air required for combustion cannot be calculated. For some time to come this will be a "cut and try" process until the best operating condition has been determined. B. T. U. per ton of steel will be the determining factor and a close check on this value will indicate the most efficient operating condition. This condition will change with the life of the furnace, so it appears that the technical staff will not have their duties reduced with the introduction of fuel meters, if the best use possible is to be made of them.

This same condition exists in rotary cement kilns fired with natural gas, and we have found that careful supervision has resulted in surprisingly large reductions in the fuel bill.

In the past furnaces have been operated on natural draft and very few attempts have been made to measure the incoming air. With the electrically operated flow meter it is possible to measure the incoming air with a loss of pressure of less than 1/10 inch of water. With the advent of combustion control, blowers are being used in order to produce the necessary static pressure for control of the air flow and it becomes a simple matter to measure the air delivered to the checkers.

An air meter should be used for each fuel meter, so that the air supply may be regulated to fit the particular reading of the meter. If the relation between fuel supply and air supply is determined, it is possible to use orifices of the correct capacity in the two lines, so that for the same position of the two indicators the desired air is admitted. It is possible to go a step farther and have two hands on the same indicator, one for air, the other for fuel, so that a glance will show whether or not the proper relation exists. This can be accomplished automatically without any great complication and it will probably become standard practice within the next five years.

Draft:

At best the open hearth furnace is a very leaky structure. It is impossible to make tight joints at the doors and the brickwork does not remain tight for a very long period of time, even if it is absolutely tight to start with. Consequently, the only way to prevent large leakage of gases is to maintain practically balanced draft conditions in the hearth. If there is a pressure in the furnace, there is a serious leakage of gases around the doors and through the walls, resulting in serious burning of the setting. If the pressure is less than atmosphere, there is a large infiltration of cold air. This lowers the combustion temperature and the temperature of the gases passing through the checkers. As a result there is not as great an amount of heat absorbed by the incoming air and the B. T. U.'s required per ton of product increases.

The usual method of control is by means of a stack valve. In the past the valve has consisted of a flat plate in the connection to the stack and the draft was controlled by lifting this plate more or less. This was an inconvenient arrangement and very seldom used. Now there are motor operated valves on the market and it is a simple matter to control the damper, in accordance with impulses generated by some sort of pilot mechanism, actuated by the pressure in the hearth.

It is much more convenient to use electric transmission of the impulses and operation of the valve than to use mechanical means. Of course, the actual draft must be transmitted to either a diaphragm or a liquid sealed bell which, in turn, produces the necessary actuating impulses. Diaphragms are of necessity limited in size so that either the power or draft measuring accuracy is limited. In the case of a bell floating on mercury, there is no friction of motion and as the bell can be made very large, the actual draft required for motion can be reduced to a few hundredths of an inch of water.

One important point to be observed is that the draft or pressure used to control the stack valve must be the normal value for the actual condition; that is, there must not be any derangement of the conditions where the pressure connections are made. Because of this condition, it is best to make several connections to the hearth. With only one connection, it is quite possible that cold iron may be so charged as to divert the gas flow through the furnace

and produce abnormal draft conditions in front of one connection, although it is hardly possible for this to happen with two or more connections.

In several installations that we have made, four drafts have been indicated on a multiple draft instrument and two have been recorded. The first pair of indicators are connected with the risers from the checker chambers to the furnace at a point just above the level of the charging floor. The two recording gages are also connected at these points so that a permanent record is made of the pressures and drafts at these two points. In addition, the record shows the time of reversals very clearly.

Draft indications taken at this point in the furnace offer outstanding advantages, in that balanced condition on each end can be readily obtained, and the amount of this draft is a relative criterion of the draft on the bath. Draft instruments at these points add materially to better results in the operation of the furnace, and with dial type indicator and recorders available that are practical there is really no reason why each furnace should not be equipped with these instruments.

The second pair of indicators are connected at the outlet to the checker chambers so that by observation of two gages, the drop through the checker chambers can be obtained at any time.

Practically all draft gages are mechanically operated and the conditions are not such as to warrant increasing the expense and complication by transmitting the records electrically. It is an advantage to have an electrical drive for the charts of the two draft records and this practice is becoming very general.

In order to obtain correct draft and pressure readings, it is necessary to transmit the actual draft or pressure to the instrument. With the jolts and jars occuring on the charging floor, it is almost impossible to keep small piping tight in the joints. The lines should be as short as possible and copper tubing is better than pipe, although care must be used to see that there are no sags to serve as moisture pockets. Where the connections pass through the furnace wall, the portion subjected to high temperature should be made of some heat-resisting metal and provision should be made on the outside for rodding out the connection, should it prove necessary.

Temperatures in Flues:

In the past it has been customary to reverse the furnace on time intervals, that is, every 15 or 20 minutes for example. However, lately reversing on a definite temperature at the outer end of the checkers has been advocated, and it appears to be the concensus of opinion that reversal on temperature gives more uniform conditions than reversal on a time basis. There are patents covering the automatic reversing based upon temperature, but of course manual reversal upon reaching definite temperature can be resorted to without any patent complications. Control pyrometers, set to ring a bell or light a light at any temperature serve the purpose very well, and are being more generally used right along.

Composition of Exhaust Flue Gases:

The ideal condition for operating a furnace would be one in which there was a minimum amount of excess air in the gases leaving the furnace at all times. A CO_2 recorder will give a record of CO_2 in the flue gases. During a good portion of the heat the CO_2 record is a fairly good indication of the percentage of excess air in the flue gases; that is, the amount of excess air supplied for combustion. During certain periods of the heat the bath gives off CO_2, so that the record of CO_2 must be somewhat discounted in consideration of excess air. A number of our CO_2 recorders are in service, and the indications are that the information which they give is of sufficient value to warrant the installation. The hand Orsat for gas analysis has been the standard method for a number of years. Our CO_2 recorder works on the same principle, that is, the absorption of CO_2 from a measured sample of gas, by means of a solution of KOH and then determination of the shrinkage in terms of CO_2. This we believe is a better method than any indirect method which depends upon the density, conductivity or other physical property of the gas mixture as a criterion of CO_2 content. There is a motor operated positive pump which pulls a continuous sample of gas through the machine, and, in addition, operates the analysis apparatus to produce periodical determinations. With a positive pump there is little danger of the sample line being stopped by liquid or soot. A satisfactory filter for insertion in the flue has been developed and with the use of the proper materials for the filter and sample line, troubles have been greatly reduced. With a reversing furnace, it is imperative that two sample tubes be used, one for the outlet from each checker chamber unless the sample connection to the CO_2 recorder is changed with each reversal so that the sample is taken from the discharge side of the furnace, the results will be worthless. This is accomplished by means of an electrically operated reversing valve operated from contacts on an operating lever on a cable. The record of CO_2 is electrically transmitted to a panel on the operating floor containing an indicator and a recorder. In order to accomplish all of these things easily and simply, it is almost imperative that electrically operated instruments be used. It is important that short piping be used with any CO_2 recorder if real good results are to be obtained, and in order to meet this desired condition electrical transmission must be used.

From the data on air leakage given earlier, it is probable that more consistent results would be obtained before the gases enter the checker chamber. This could be done by some changes in the type of filter and connections used.

There are at least two oxygen records coming on the market, which produce a record of the percentage of oxygen in the flue gases. It is claimed that a record of O_2 is a better operating criterion than a record of CO_2 because the oxygen in the gases is the constituent that causes loss by oxidation of the metal in the bath, as well as an indication of loss by excess air to be heated. Of course, with air containing 20% oxygen, a slight air leakage will increase the percentage of oxygen very rapidly. For example, if flue gases contain 1% free oxygen then 10% leakage will represent 10% of 20% oxygen or 2% free oxygen added to the products of combustion. This is twice the original amount making an error of 200%. In the case of CO_2 in the flue gases air

leakage only serves as a diluent, that is, 20% added air will only reduce the apparent CO_2 16-2/3". This indicates that the gas sample will have to be taken as near as possible to the hearth if indications of any great value are to be obtained. Of necessity, an oxygen recorder will be complicated and expensive. There has been quite some interest in these instruments, but to my knowledge only one experimental installation is in operation. There is only one type of instrument that has been in service in Germany for some time and I understand that arrangements are being made to introduce it in this country.

We have discussed the possibilities of indicating and recording the various data which has to do with open hearth furnace operation. It appears that after this rather elaborate introduction, it is time to discuss the real subject of the paper, that is Mechanical vs. Electrical Devices for Combustion Control. It should not be necessary to bring up the various points about electrical control before an organization with a title such as this one possesses. However, it will probably be worth while to enumerate several of the advantages.

1—Electric operation of instruments makes it possible to have very short pressure connections between the device in the pipe which produces the differential pressure and the secondary device which converts the differential pressure into readings of flow. Short connections mean that the effect of temperature variation is practically eliminated. The meter body or secondary device is located in a warm place where it can function properly in cold weather, and it is also out of the way where there is no danger of being damaged by any material that might be dropped or skid around on the operating floor.

2—Short connections mean that it is possible to keep the connecting pipes tight. With the jarring to which the open hearth building is subjected, it is difficult to keep small sized pipe joints tight. The use of soft annealled copper tubing and compression fittings makes it easier to keep connections tighter than with screwed pipe, but even so, short lines are good insurance for contained satisfactory operation.

In the measurement of gas and air, the differentials used are only a few inches of water, and consequently, the connecting pipes must be so run that there is no possibility of water being trapped, because water pockets, which will reduce the pressure on one side a fraction of an inch, will produce an error that would destroy all value in the meter record.

3—In order to get full return on the investment in meters, it is necessary that the records or indications be in plain sight of the first helper. It is obvious that if the operating man is required to travel some distance in order to read his instruments he will not observe them nearly as often as he will if they are in plain sight at all times. The electrical operation makes it possible to have indicators in plain sight that can be seen from a distance of 30 to 40 feet, and if the recorders are segregated in a closed house, they can be conveniently read and serviced and be entirely free from danger from dirt, fumes or mechanical damage.

4—The principle on which the Republic CO_2 recorder operates is chemical, because after spending some fifteen years building CO_2 recorders and experimenting with all of the different principles of operation, we still feel that the potash absorption, or in other words, the Orsat principle is the best one so far developed. This machine is electrically operated in that it is motor driven, having a positive pump which continuously draws the sample of gas from the furnace and discharges it into the atmosphere. Then the cycle of analysis is also driven from the motor. In addition, there is an electric reversing valve which reverses the sample connections to the proper set of checkers whenever the furnace is reversed.

Electrically Operated Equipment for Automatic Combustion Control for Open Hearth Furnaces *

By B. F. KEENE †

The last few years have seen remarkable advances in open hearth practice. Among these advances has come the recognition of electricity as a motive and controlling force. In many plants hydraulic or pneumatic drives for charging doors, reversing valves, etc., have been replaced by electric drives. Further, instruments and control have been provided to supplement the eye and judgment of the first helper as guides to good operation. With a definite tendency today toward electric drives and toward automatic controls it has been a logical step in the progressive march toward good economy in open hearth practice to adopt electrically operated automatic controls. Such controls possess advantages of simplicity, flexibility, reliability and low operating and maintenance costs which are always associated with properly designed electrical installations.

There are two well-known types of electrically operated control for open hearth furnaces on the market today. These are metered combustion control and automatic reversal from temperature difference. Although the two controls supplement each other in their action and a combined installation results in the greatest economy of operation, the function of each control is quite distinct. The purpose of this

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† Leeds & Northrup Co., Philadelphia, Pa.

paper is to describe in brief form the electrically operated equipment used in only one of these systems, the metered combustion control.

To understand the features of a control unit it is necessary to have some conception of the system of which it is a part and of the function it performs in the control system. This picture can best be presented by a discussion of one or more applications of the control.

In general it can be said that the object of automatic control is to perform automatically those functions which have been performed manually and to improve on the manual performance. The object of metered combustion control is to provide a simple means of keeping the combustion rate in accord with heat demand and of maintaining combustion efficiency and correct furnace pressure. With effective control the most efficient use of fuel and the most advantageous furnace conditions are maintained. This naturally results in decreased fuel per ton of steel, a shorter melting time and a longer life of furnace refractories.

Efficient operation of an open hearth furnace requires simultaneous adjustments of various controls. Regardless of how good the first helper is and of how full a complement of instruments he has available to guide him, he is limited in the number of adjustments he can make at any one time. With a poor first helper the results accomplished are of a proportionately lower grade. It is, therefore, only logical for the management to place in the hands of the first helper a tool, in the form of automatic combustion control, which will make the required adjustments simultaneously and in the most efficient manner.

A control comprising a number of properly correlated electrical devices can be provided to make automatically the routine adjustments of fuel and draft which, under manual control, are made by the first helper. It takes into account the flow of air to a furnace, the rate of fuel supply and the furnace pressure. It responds automatically to a single combustion rate adjustment made by the heater and regulates the draft and fuel to give the most satisfactory combustion conditions and the most favorable furnace pressure. Simple means are provided for the first helper to make manual readjustments of the air supply during the lime boil period.

In a well laid out electrical system the devices going to make up the control system can be divided into two groups. One group consists of those devices which will provide a push button control and the other group consists of those devices which, with the push button control, go to make up an automatic control.

In the push button control class we have the motor drive units with their reversing relays, limit switches, etc., which are required for the regulation of dampers and control valves. These units, with their centralized push button stations for actuating them and signal lights for indicating their limits of travel, form the push button control system. All these devices which are regulated from push button stations can be and, in an automatic control system, are operated automatically by controllers.

In the automatic control class fall the air flow, fuel feed and furnace pressure controllers. The air flow and fuel feed controllers actuate their respective motor drive units automatically and in immediate and proportionate response to heat demand as represented by a manually adjusted rheostat. The furnace pressure controller actuates its drive unit to maintain furnace pressure at a predetermined constant value.

The controlling and actuating mechanisms can be assembled in one of several ways to accomplish the specific ends desired in the operation of a given installation. The use of electricity as a controlling force permits location of the individual actuating devices where most convenient, while controlling and indicating devices can be assembled at a central control point. Further, the use of electricity permits of great flexibility in the selection of the type of control, in the adjustment of the controllers and in interlocking of the control system. As an illustration it might be pointed out that the first helper can choose between manual regulation, push button regulation and automatic regulation of draft and fuel simply by turning a selector switch. Further, he can change the ratio of the fuel and air supplies by simple adjustments at the central control point. The protective features will vary somewhat with the type of installation but, generally speaking, the control is protected against failure of the master loading force and against undesirable combustion conditions due to limitations in the control range of the draft equipment or fuel supply equipment.

Before considering the application of the control devices in a system it is desirable to give some thought to the devices themselves. The controller most familiar to us all is the furnace pressure controller. This controller is a balance responsive to pressure in the furnace and to the tension of a loading spring. Its major elements are shown in the illustration of this unit forming a part of the typical control layout shown in Fig. 1. An oil-sealed bell is mounted on one end of a pivoted balance arm. The space under the bell is connected to a tap in the furnace so that the balance beam responds to furnace pressure. Changes in draft supply tend to upset furnace pressure and to thus apply a force to the controller tending to upset equilibrium of the balance.

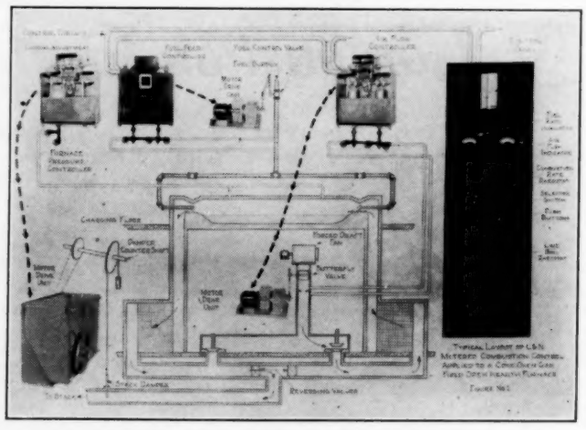

FIG. 1.

To a vertical projection of the balance arm is attached one end of a loading spring. The opposite end of this spring is attached to an adjustable graduated sliding scale which can be clamped in any position. The force applied to the balance arm is due

to the tension of this loading spring and is constant for any setting of the sliding scale. This force opposes that due to furnace pressure and when the two are equal the balance is in equilibrium. Furnace pressure is then at a predetermined constant value.

When either force is in excess of the other the beam deflects in the corresponding direction, closes an "increase" or "decrease" contact and completes a circuit through a relay which actuates the reversible motor of the drive unit regulating the stack damper. The stack draft is thus changed until the pressure under the bell counterbalances the pull of the spring. This change in draft restores the equilibrium of the balance beam and opens the contact in the relay circuit, thereby stopping the motor drive unit.

The air flow controller is a balance similar in construction to the furnace pressure controller. The major distinction is the addition to the balance arm of a second pressure bell and the replacement of the loading spring with a set of coils through which a control current flows. The balance is responsive to air pressure differential and to changes in electric control current. Its elements are shown in the illustration of this unit in Fig. 1. The spaces under the oil-sealed bells are connected across an orifice in the air supply duct to the furnace so that the balance beam responds to changes in air pressure difference. The force tending to upset equilibrium of the balance varies with the rate of flow of air to the furnace and is a measure of that flow.

On the vertical arm, which forms a part of the balance, is mounted a coil which moves laterally between two fixed coils when the beam moves. The three coils are connected in series electrically in the control circuit. With control current flowing in the coils they become electromagnets and their combined effect is a pull on the beam through the movable coil, the force of the pull depending upon the strength or magnitude of the control current. This current is responsive to heat demand and is manually adjusted by the first helper using a simple rheostat. The pull due to the control current opposes that due to pressure difference and when the two are equal the balance is in equilibrium. The air flow then bears a definite relation to the control current.

When either force is in excess of the other the beam deflects in the corresponding direction, closing an "increase" or "decrease" contact, and completes the circuit through a relay which actuates the reversible motor of the drive unit regulating the air supply. The air flow is thus changed until the difference in pressure at the bells counterbalances the pull of the current coils. This change in air flow restores the equilibrium of the balance beam and opens the relay circuit, thereby stopping the motor drive unit at the new position.

From the preceding description it is evident that the air flow controller will maintain a definite relation between the rate of air flow to the furnace and the control current flowing through the coils of the controller. It therefore follows that if the first helper sets the control current in accord with the heat demand the flow of air to the furnace will be maintained proportional to that demand. Changes in control current are effected by changing the value of the resistance in the constant voltage control circuit. This is accomplished simply by turning a rheostat called the "combustion rate rheostat." For intelligent operation, the first helper must have some indication of the change made whenever he adjusts the rheostat, and this is accomplished by providing an indicator in the control circuit calibrated in arbitrary units of 0 to 100, 100 representing maximum air flow.

The most important element in an automatic system for meeting the demand for heat and for high combustion efficiency is the control of the fuel supply or supplies. To carry out this function fuel feed controllers of various forms are used dependent upon the type of fuel burned. As a rule, the fuel feed controller is similar in construction to the air flow controller. It always functions to definitely proportion fuel supply to the control current which, under normal operating conditions, is the same control current as that supplied to the air flow controller. This means that, with fuel and air supplies held in proportion to a common control current, a definite relation between the two supplies is maintained. As is the case with the air flow controller, an indicator is provided to indicate the rate of fuel supply in arbitrary units of 0 to 100, 100 representing maximum fuel rate.

In the case of a furnace fired with coke oven gas, the fuel feed controller is similar throughout to the air flow controller. Such a unit is illustrated in Fig. 1. The function of the controller is to measure the gas supply to the furnace by taking the pressure drop across an orifice in the gas supply main and to hold this supply in definite relation to the control current. A device is provided with this controller which makes it possible to change the fuel-air ratio quickly and readily to meet changes in fuel quality or erratic conditions of fuel feed. This device simply changes the relation between fuel supply and control current. Since the ratio of air flow to control current is unchanged, the net result is a change in fuel-air ratio. An equivalent device is provided with each type of fuel control.

During the lime boil period it is necessary to make a major change in the ratio of air to externally supplied fuel in order that an excess of air may be provided to meet the change in bath conditions and to burn to CO_2 the CO given off by the bath. This change is accomplished simply by turning a selector switch at the control panel to a position identified as the "lime boil" position. By so doing, the air flow controller and its indicator are automatically transferred from the main control circuit to a separate circuit consisting of these units and a "lime boil" rheostat; the fuel feed controller and fuel rate indicator remain in the circuit with the combustion rate rheostat. It is now possible to make necessary major adjustments of the air flow by turning the lime boil rheostat to meet bath conditions. The relative supplies of fuel and air are shown by their respective indicators. When the selector switch is returned to its normal position the fuel and air supplies are again responsive to adjustments of a common control current as previously described.

The accuracy and sensitivity of the controllers and the flexibility of the control system constitute one phase of the control. Equally good provision must be made for the other phase of the control, involving the equipment used for transmitting the control action to the regulated devices. Sturdy, robust elements capable of developing comparatively

high forces, with a minimum of lost motion are required. For this purpose it is only natural that a proven type of apparatus, like the motor drive unit, be used.

Each damper, valve or fan motor rheostat subject to regulation is operated by a motor drive unit. The characteristics of the unit, such as capacity, speed, etc., vary with the device controlled. In general, each drive unit consists of a high ratio reduction gear, driven by a reversible electric motor. The heavy-duty gear unit is carefully designed to meet torque requirements and to minimize lost motion. The sturdy motor has ample power to operate the gear. Switches are provided to limit the motion of the drive unit to the travel of the driven device while signal lamp indications of these limits are given.

The use of electrically operated controllers makes it possible to design simple, accurate apparatus to detect minute draft changes and to convert and magnify those changes into forces several thousand times the original force. Mechanically interlocked reversing relays are provided to step up the relatively low current for actuating the drive units to the actual value required at the drive unit motor. These relays are designed to meet severe operating conditions such as are imposed by a highly variable load which is frequently reversed.

The control panel equipment is comprised of apparatus required to adjust the control current, select the type of control and indicate rates of fuel and air supplies. The units of the control panel equipment and their functions in the control system have been described in considering the operation of the individual controllers.

In describing the function of each major element of the control system, Fig. 1 has frequently been referred to as illustrating the unit. If the arrangement shown in this figure is considered in its entirety, the application of the control elements in a typical layout of metered combustion control is evident. This layout also shows the interrelation between units and serves to further clarify the function of each unit.

Electrically operated automatic control possesses many advantages in any type of installation. Where two or more fuels are burned in the same furnace, electrical control possesses a distinct advantage from the fact that it enables several fuel supplies to be added electrically. This will be more obvious if we consider the diagrammatic layout in Fig. 2.

In the arrangement shown, a furnace is fired with producer gas, blast furnace gas and coke oven gas. For like volumes of each of the gases, different volumes of air are required for complete combustion. It therefore follows that for satisfactory operation it is necessary to either proportion air supply to each fuel separately or to add the fuels in terms of common units and proportion the air supply to the sum of these units. The former involves separate duct arrangements, separate damper controls and a complex layout. The latter arrangement, by using electricity as the controlling medium, is accomplished in a very simple way.

Each fuel has its own fuel feed controller whose function is to measure its fuel supply and proportion

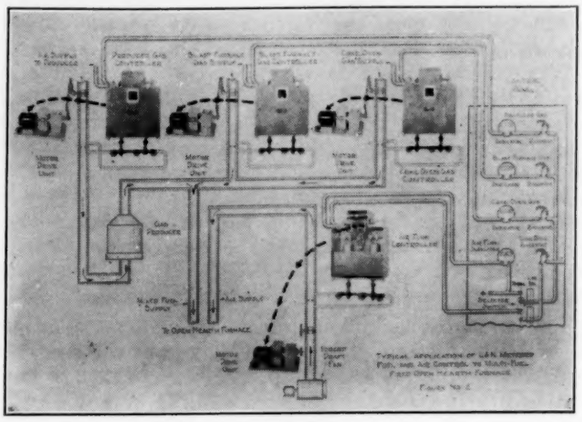

FIG. 2.

that supply to its local control current. The strength of this current is adjusted by its own fuel rate rheostat and its magnitude is indicated on its own fuel rate indicator. Each fuel feed controller is adjusted to provide a definite volume of its fuel for each unit of control current. For instance, in one case a unit of control current might represent one volume of fuel while in the case of another fuel, requiring less air per cubic foot of gas, the ratio might be one unit of control current for three volumes of fuel.

In the arrangement shown in Fig. 2 a coke oven gas controller measures the coke oven gas supply and holds it in a predetermined definite ratio to its control current; likewise a blast furnace gas controller holds the blast furnace gas supply in a definite predetermined ratio to its control current. The gas output from a producer is proportional to the air supply to the producer and thus the producer gas controller measures this air supply and holds it in a predetermined ratio to its control current. In the electrical control circuit the fuel controllers are in parallel with each other and are in series with the air flow controller. This means that the air flow control current to which the air flow controller is responsive is equal to the sum of the fuel control currents. It therefore follows that, since the function of the air flow controller is to proportion air flow to its control current, the air flow is held in proper proportion to the total fuel supplies. This ratio holds regardless of the distribution of the fuel supplies as this distribution is only affected by changes in the respective fuel control currents which in turn cause the proper changes in air flow to be made.

To sum up the features of electrically operated automatic controls, we can safely say that accuracy and sensitivity of control response, flexibility of operation and adjustment and a simple convenient means of adding fuels are in the forefront. Where the proper selection and installation of electrical equipment is made, no question of cost of operation, cost of maintenance and reliability of equipment exists.

*Electrical vs. Mechanical Devices Used in Connection with Combustion Control Apparatus**

By W. M. SHALLCROSS†

This subject, as given to me—"Electrical vs. Mechanical Devices Used in Connection with Combustion Control Apparatus"—is a delicate one to handle.

A recent traveler in Africa was once put into a similar delicate position. He was visiting a friendly Cannibal Chief and after attending one of their banquets he was asked his opinion on "Roast Pork vs Roast Humans as an Article of Diet."

Now the Chief's friendliness might lack permanence so the guest tactfully remarked that although it was largely a matter of taste, **he** preferred roast pork because he was brought up on it.

So with control apparatus—it is often a matter of taste but **we** prefer electrical methods because we were brought up on them.

The subject of electrical vs mechanical means can best be considered by looking at it successively from 10 separate points of view:

1—Accuracy of Operation.
2—Reliability of Operation.
3—Simplicity.
4—Convenience.
5—Ease of Installation.
6—Maintenance.
7—Power and Ruggedness.
8—Operating Medium.
9—Safety.
10—Cost.

1—Accuracy of Operation

Under the first item—**accuracy** of response—the electrical control has not so much of an advantage. A correct control requires that the motor element of the control should move with a speed roughly in proportion to the deviation from normal of the condition being regulated. An example—a pressure regulator valve should move slowly if the regulated pressure changes but slightly from normal and it should move rapidly on a greater deviation. Simple electrical controls do this but it is easier to obtain a more complete result with a mechanical control—where the pressure element opens a pilot valve proportionally to the pressure deviation.

On the other hand, if this action is carried too far hunting is liable to set up and a more or less elaborate compensating device must be added.

The next item to consider is the **quickness** of response of the control parts to the impulse which is to set it in motion, except for the few mechanical parts, which unfortunately cannot be entirely avoided, electrical impulses are lightning quick. No matter what distance separates the control parts the impulses are transmitted instantly, avoiding the time lags due to mechanical lost motions.

The next item—**permanence** of response—requires that the operating characteristics shall not change materially as the control parts wear during service. It is a simple matter to arrange the parts of an electrical control so that the wear is concentrated on a few parts, these parts made large and of long life, and—most important of all—the parts openly exposed for inspection. Removal of inspection covers permits this inspection and adjustment while the control is uninterruptedly operating.

2—Reliability of Operation

In the old days the greatest objection to electrical controls lay in the unreliability of the power supply. You all know how rarely nowadays the power goes off, especially if it is a Public Service supply.

Moreover, since more and more steel plant equipment is now being electrically driven—in fact, some of the most important units,—the infrequent power failures will practically shut the plant down anyway and the controls are not then needed.

It is believed by many that today the plant's electrical supply is as reliable or more so than its supply of air or water. Electric wires need neither strainers nor pressure governors, and have no messy leaks. There is no such thing as an electrical leak. If a leak starts, something immediately burns, the fuse blows and the signal lights go out.

Also—in the old days—electrical parts were quite flimsy but nowadays it is different—wiring is run in conduit, knife switches are enclosed and all parts are better protected.

Simple signal lights show at once whether the control is dead or operating properly. It is usually necessary to watch a mechanical device for a while to determine whether it is alive or dead—or to note an erratic behavior of the gauges.

Last—and of great importance—the failure of power will stop the electrical control device and it will stay in that position, neither closing nor opening erratically. If a mechanical device falls either shut or open on its power failure a dangerous condition might exist.

In short, it appears that electrical devices nowadays are as reliable as those purely mechanical, **but** —at times of failure (and there will always be some) it is easier to show warning signals on the electrical devices.

3—Simplicity

There is no fundamental reason why the electrical or the mechanical device should be the simpler. Either one can be made simple or it can be made

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† President, Shallcross Control Systems Company, Milwaukee, Wis.

complicated. To be simple, the electrical as well as the mechanical, device can and should be constructed with rugged, well developed parts, and with no small delicate features.

Some wise man has said: "Any fool can make an intricate machine that will work—it takes a genius to make it simple."

It is usually possible, because of the electrical device's quickness of response, to avoid the necessity of a compensating device to correct for time lags, thus simplifying the control.

There are what we may call two schools of thought in control design. One school believes in a control which gives hair line results with a device which is intricate and expensive to maintain. The other believes in a control which gives results sufficiently good for the purpose with a device which is simple and cheap in maintenance.

4—Convenience

If a control device is easy for the operator to handle and adjust, the installation will be so much the more efficient. Push buttons are very simple and with these the operator of an electrical control can change the setting of a distant control unit, operate his valves manually, re-adjust a flow ratio, and such things. Electrical devices can also bring back to him indications of these adjustments as they are actually made.

Furthermore, these simple wires can stretch any distance, permitting all his manual operations and indications to be gathered together on a convenient control panel where he can also have his various gauges. So also can the Superintendent do his operation eaves-dropping in the upholstered luxury of his mahogany office chair.

5—Installation

Both electrical and mechanical devices are about equally easy to install. Electricians can run wires and conduits as easily as pipe fitters can run pipes. If, however, the mechanical device requires cables and sheaves or rods and bell crank levers the advantages both as to ease of installation and compactness lie with the electrical.

6—Maintenance

Maintenance is also about the same on both. The electrical control has some advantage—first, because the wearing parts are exposed to view after the removal of inspection covers and these parts can be observed under actual operation. Secondly the signal lights of the electrical control give instant warning of wrong doing and can even be made to give forewarning before attention is required.

It is an unfortunate fact that most of the troubles experienced are in the mechanical parts of the electrical control.

7—Power

Electrical and mechanical devices can both be made as powerful as necessary to move the heaviest valves and parts. Electrical controls have one peculiarity to themselves. Because they consist of a high speed motor driving through a high ratio gear reduction the delivered torque is enormous.

Hence, if a valve gets dirty or the load resistance builds up in some way, the control will keep on moving and clear the obstruction but will not lie down. Of course if the load is too great—say, a monkey wrench gets into the works, something may break before the fuse can blow. Either of these happenings will be reported at once by the signal lights.

8—Operating Medium

As mentioned earlier, the choice of the operating medium, whether electrical or mechanical, is often a matter of taste. Some operators prefer oil, some water, others air and some electricity. However, if a motor is to be used to drive an oil pump or an air compressor for the control, why not have it operate the control direct?

Electricity is becoming so widely used that practically every plant, no matter how small, now has at least one electrician who can usually do everything from putting in new lamp bulbs to de-magnetizing his watch.

Of course these electrical controls must be simple and foolproof above all else. An intricate control, either electrical or mechanical, has absolutely no place in a small plant—nor in a large one for that matter.

9—Safety

If one carelessly experiments with an electrical control he will be shocked. We are, however, so accustomed to electrical apparatus and this apparatus is now so completely enclosed and safeguarded that its safety hazard is now generally considered as good as mechanical equipment.

All operating adjustments must be completely isolated from live parts and—as is the general practice—all the maintenance adjustments made by electricians who know what they are doing.

Here, now, is an important observation, which does not apply to safety particularly but to the entire performance and usefulness of the control. It is in the nature of a protest.

We have found (and we think other control makers have found the same thing) that a very great number of the troubles that have to be straightened out in a new control installation are the result of experimenting with the adjustments by someone unauthorized and usually unknown,—plain "monkeying." Someone with inquisitive fingers or a new pair of pliers wants to see if he cannot improve things by changing some of the adjustments. His motives are probably as pure as the lily but his results are as black as the skunk cabbage.

We accordingly insist that the plant arrange to have one man and one man **only** look after the controls. We have even provided locks on inspection covers in some plants.

This trouble, however, usually dies out after 3 or 4 weeks of operation—the novelty of the new machine has worn off.

10—Cost

There should not be much difference in cost between mechanical and electrical controls. If a control is slow and sluggish and needs a compensating device it is costly to manufacture. It costs about as much to build a simple fool-proof machine as it does an intricate and delicate one.

It must not be expected that combustion controls, mechanical or electrical or any kind, will ever be turned out with production methods and assembled on one of Henry Ford's assembly racks. A control consists of an assembly of certain standard units. These units can be made and kept in stock

but they can be assembled into a finished control only with sometimes considerable engineering to fit them properly into their particular job.

Controls cannot be priced at so much per pound for iron, brass or copper. A man, for example, is worth (at current prices for good meat, bone and fat) about $37.50 but—add an active brain and what is he worth?

Conclusion

As we grow older and look around us at an advancing civilization we notice that more and more things are being done electrically. They range from the steel mills' heaviest rolls to the insignificant doorbell, now pushed electrically instead of yanked mechanically.

We ride in trolleys instead of being jerked along by a cable, or else we let an electric motor start our car instead of breaking our back and wrist over the crank. We telephone instead of yelling down a speaking tube and even the hated alarm clock is no longer mechanically wound but is electrically plugged into the wall.

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*Discussion of Regulators for Open Hearth Combustion Control**

By R. W. SIMPSON †

Combustion control for the Open Hearth is still a new, but proven fact. However, there are many points yet to be learned, and it seems that in the present stage of the art, it is a little early to speak of the advantages of one type of regulator over another.

The demands on a regulator for open hearth control are more varied and more severe than that made by boilers or other types of furnaces. The open hearth at every reversal must shut off gas and air, and the regulator must go from maximum to zero—and then be returned to maximum after reversal. In addition, the regulator must respond to the changes of small proportions when the first helper has a slight variation in his fuel and air requirements. It must also respond to the differences in fuel and air requirements in the melt down and finishing stages of the heat, the latter being from 1/2 to 2/3 of the former.

The fact that all three types of movement must be accomplished in approximately the same time interval, sets the problem for the regulator manufacturer, and presents one of the most difficult of all regulation problems. A regulator attuned for speedy maximum—minimum movements will in general hunt when called upon to make the smaller changes—one attuned for the smaller changes will defeat the purpose of regulation by being much too slow for the larger changes.

A regulator of any type consists of a bell or diaphragm as a pressure responsive means balanced by a lever against a weight or another pressure responsive element. A movement of the lever arm will cause an outside source of energy to act in closing or opening a valve to restore a balance in the regulator. Too quick movement will cause over-traveling—too slow movement will introduce undesirable time delays. Therefore, the question of selective compensation arises so that the regulator will respond properly for all kinds of demands upon it, that is to move quickly for large changes in flow requirements, to move slowly for small changes, and to move with intermediate and proportionate speeds for all intermediate requirements.

The method of accomplishing this with one type of mechanical regulation I propose to outline briefly—(See Fig. 1). The principle of this can be seen from the accompanying sketch. An increase in pressure causing the right hand bell to rise, working through the lever arm and linkage to the pilot valve,

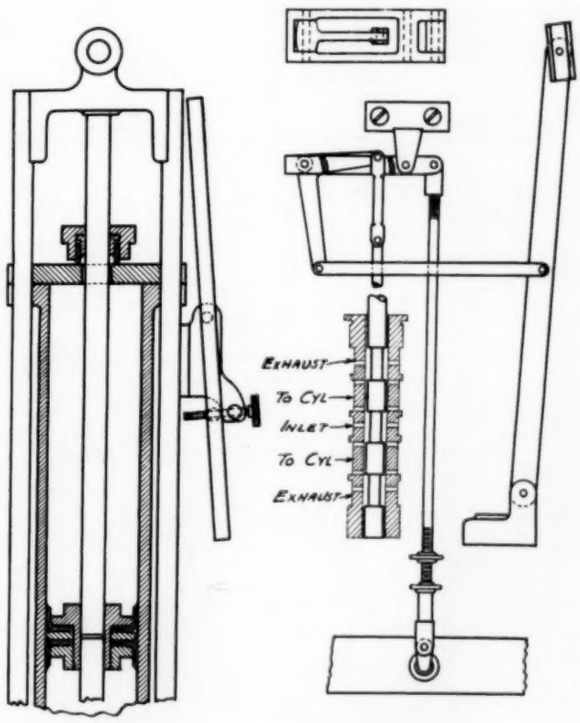

FIG. 1.

will admit air to the bottom of the cylinder and release pressure from the top of the cylinder, the pilot valve acting as a three-way valve. With the movement of the piston and crosshead, an angle bar,

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† American Heat Economy Bureau, Inc., Pittsburgh, Pa.

moving with the crosshead by means of a rolling or sliding contact, acts through the toggle linkage to move the pilot valve in the opposite direction from that imparted by the lever arm connecting the bells; in other words, closes the pilot valve, so that movement of the regulator ceases.

With only a slight change in pressure, the bells will move very little just cracking the pilot valve, admitting a small amount of air to the cylinder and after a slight movement of the crosshead, the pilot valve is quickly closed. With a maximum change in pressure, the bells will move a large distance opening wide the pilot valve, admitting considerable air to the cylinder causing a large movement of the crosshead before the pilot valve is closed. For all intermediate movements, the same action is proportionally true.

In this description, the medium for operating the power cylinder has been given as compressed air, but an oil pressure system will work in all ways just as satisfactorily. The only difficulty with oil is to secure tight lines which will eliminate wastage of the oil from the system.

As will be seen, the principle of selective compensation applied mechanically will cause a speedy action of the regulator for all movements of the controlled valve, without over-traveling.

This applies to the control of the fuel and air, and in particular to control of the draft. At reversals the furnace pressure changes very little in actual measured figures in spite of the fact that no fuel and air are entering, and yet the pull of the stack, waste heat fan, or high temperature fan, remains sufficient to draw out the original volume of products of combustion which means the entry to the furnace of an equivalent volume of cold air, with its cooling effect, unless regulated properly. This calls for action of the damper, coincident with the turning off of the fuel, and again with the turning on of the fuel. The lack of a regulator in itself sufficiently sensitive, and at the same time sufficiently responsive, led to the development of "Thermometric Draft

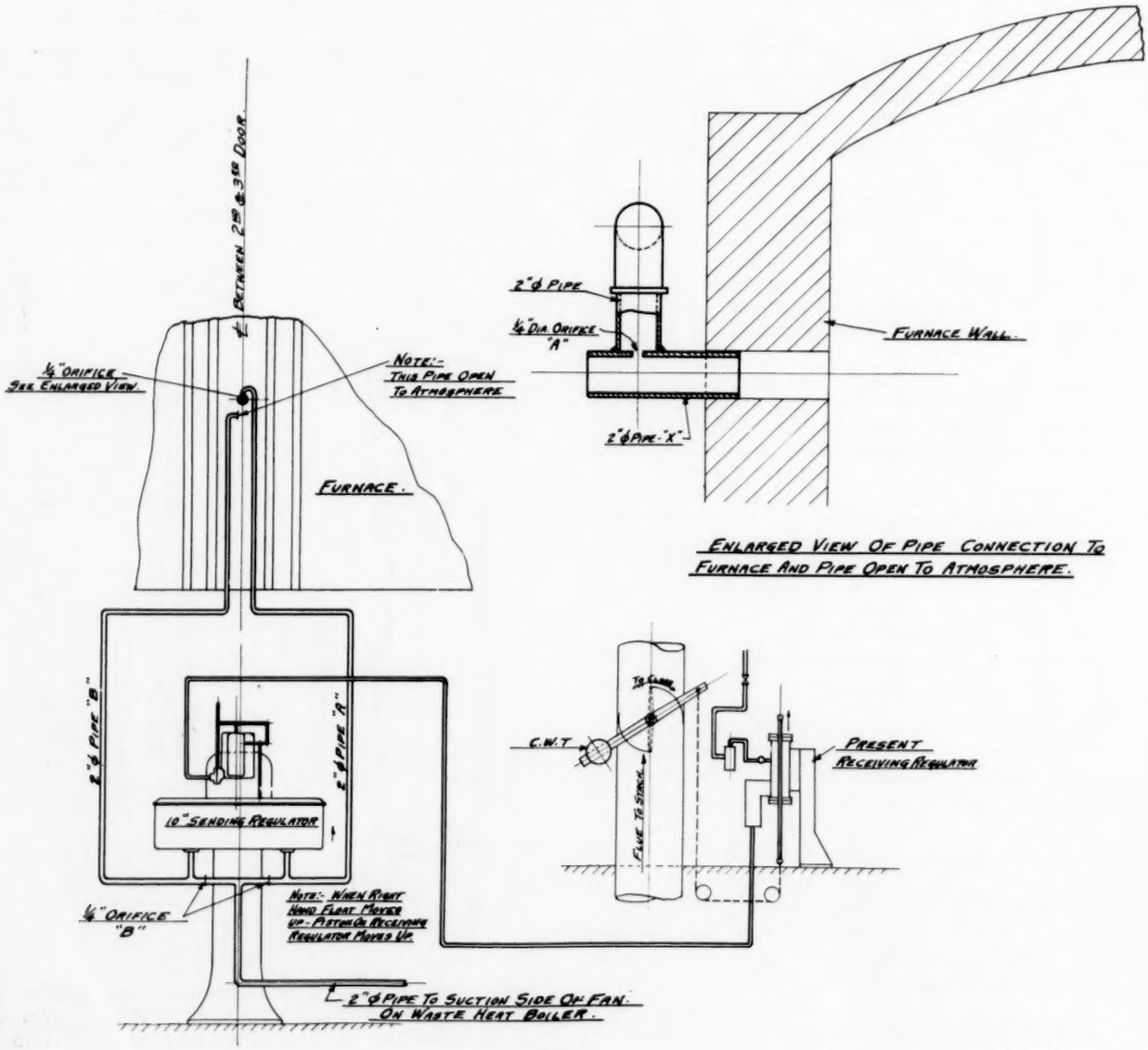
Between 2nd & 3rd Door
¼" Orifice - See Enlarged View
Note:- This Pipe Open To Atmosphere
Furnace.
2"ϕ Pipe "B"
2"ϕ Pipe "A"
10" Sending Regulator
¼" Orifice "B"
Note:- When Right Hand Float Moves Up - Piston On Receiving Regulator Moves Up
2"ϕ Pipe To Suction Side Of Fan On Waste Heat Boiler.
2"ϕ Pipe
¼" Dia. Orifice "A"
Furnace Wall.
2"ϕ Pipe "X"
Enlarged View Of Pipe Connection To Furnace And Pipe Open To Atmosphere.
To Stack
C.W.T
Present Receiving Regulator
Flue To Stack

FIG. 2.

Control." This principle magnifies the small pressure changes and with this type of control, the small impulses due to pressure variations are multiplied a hundred times, so that there is applied to the regulator an inch pressure for each .01" variation in the furnace hearth pressure. This adds to the best of regulators a substantial impulse upon which to work. (See Fig. 2).

The principle of this control is based on the fact that the drop across an orifice for equivalent volumes of gases is proportional to the square root of the absolute temperature. By pulling a constant volume of gases across an orifice in the furnace connection, there are pulled across this orifice cold air of 80° at a low pressure drop when the furnace is under suction, and hot gases of 1500° when the furnace is under pressure at a higher pressure drop. The possible differences in this pressure drop are only limited by the volume drawn through the orifice and the size of the orifice. In practice it is found sufficient to establish a 2½" drop for a furnace under pressure and ½" drop for a furnace under suction. Then by balancing the regulator, this drop may be held at any point representing a corresponding furnace pressure maintained well within 1/1000 of an inch. It is well to point out that impact velocities of the flame due to scrap piled up, driving flames against the furnace connection have no effect in themselves. The temperature of the gases pulled across the orifice is the determining factor.

With this great amplification of pressures applied to the regulator, the goal of regulation, instantaneous responsive, is more closely approached. Regulators have moving parts and therefore friction, their bells have weights and therefore inertia. These act against instant response, and consequently with the temperature measurement of draft, it becomes even more imperative to incorporate the very best type of selective compensation.

An attempt to apply selective compensation electrically, involves the installation of small variable speed motors of at least three speed characteristics, and preferably of six speed characteristics. Even in the latter case, the regulator can respond only at given speeds and not at intermediate speeds and at best would be only a substitute for the system described, and such motors involving both field and armature control are not altogether satisfactory.

In the above bell type and diaphragm type regulator have been mentioned. It should be pointed out that there is little difference in the two—the seal of the bell type acts as an elastic diaphragm, up to the limits of the seal. The ordinary diaphragm can be designed without these limits, but loses in elasticity. In consequence, the use of a particular type is an engineering question applied to the particular job.

I might point out in closing that every attempt has been made to incorporate electrical principles into turbine governors, but these still remain mechanical in practical application. The service a governor is called upon to perform is very similar to that of a regulator, with perhaps much less frequent variations than the regulator. Then until we can find a means to do this electrically, equally as well as it can be done mechanically, it appears best to recommend mechanical type regulators for the severe demands of the open hearth, bearing in mind that a successful installation calls for considerable co-operation in engineering and operation, and is not a question of just applying a regulator to the job in hand.

Discussion

The Practical Side of Metallurgical Heat Application†

By HARRY DOBRIN*

M. J. Conway: Mr. Dobrin has well presented the case for the steel plant fuel engineer, and, in this general survey of his every day problems has pointed out the importance of his position, setting a high standard for the man who successfully fills the position. As is usual in a paper of this nature and where so much ground had to be covered, Mr. Dobrin could do little else but generalize.

There are some questions which occur to me. One is in regard to Mr. Dobrin's statement that in the heating of skelp and transferring it from one furnace to another, that heating imperfections, while they may not prevent proper welding, cause surface imperfections sufficient to cause the rejection of the finished pipe. Perhaps Mr. Dobrin will explain this at length.

He has brought out very clearly the necessity of thoroughly mixing the gases with requisite air for combustion. We really have not done very much as a whole with furnace design to bring about this mixing condition especially with large furnaces. It is a point well taken and more should be done and said about it.

In the case of gas producer operation, I think we have a definite means of consistent and continual check of the efficiency by the recording of the producer gas temperature at the exit of the producer. Once determined for any particular grade of coal the operation can be checked at any rate of gasification and the check apparatus is comparatively simple to install and easy to maintain.

The meeting is now open for discussion. I would like to hear from some of the gentlemen present.

Dr. F. F. Foss: I came here to listen to what

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* Consulting Fuel Engineer, Pittsburgh, Pa.

plant operators and fuel engineers have to say about open hearth furnace "automatic control" and had no intention to talk. Accepting, however, your invitation to say a few words, I may express my reaction on Mr. Dobrin's paper.

Mr. Dobrin's paper "The Practical Side of Metallurgical Heat Application" represents a fine survey of what has been done up to the present time in a special line of combustion engineering in iron and steel industry of the United States. It shows that metallurgical combustion, or as it is often called, fuel engineering, in steel plants is still in the past century.

Mr. Dobrin has also pointed out, by the way, that fuel engineer, who is supposed to be responsible not only for the fuel economy, but also for the quality of heating, does not occupy proper place in steel plants and that in many cases he is not even consulted about fuel and furnaces. In rare cases, when he is consulted, his opinion is very seldom taken into consideration. That is why, in many instances, we see rather low efficiency of metallurgical furnaces.

When quite a young engineer, I worked in Urals, Russia, in the end of the past century. It was my fate to have in my charge, among other plants, a charcoal blast furnace, where a blowing engine driven by a water wheel was equipped with wooden cylinders and wooden pistons. The valves have been made out of leather. Such a blower gave about 20% efficiency. This picture comes to my mind when I compare the all-around efficiency of metallurgical furnaces in charge of our fuel engineers nowadays. This efficiency is also not higher than 20%, whereas the efficiency of equipment in all other branches of iron and steel industry is brought up nowadays to much higher figures. That is why I say that the present status of iron and steel fuel engineering in the United States belongs to the past century. Who is to blame for the condition?

It seems to me that first of all, the plant's general management is responsible for that and the fuel engineers themselves are to be blamed as well. In the last three decades, when iron and steel industry of the United States has achieved these tremendous proportions, metallurgical fuel was very cheap nearly in all districts of the country.

The price of fuel did not reach any dangerous levels even in the times of high demand for it. That is why very little attention was paid to the fuel economics by iron masters in the past. Only recently, when it became obvious that combustion engineering does not consist only out of fuel economies, but materially affects the quality of heating, the plant manager has turned his eyes to the fuel engineer. Notwithstanding this, however, up to the present time there are only very few enterprises in iron and steel industry, which have highly efficient, scientifically managed fuel engineering departments.

The larger number of steel companies do not make even a general survey of fuel application in different plants correctly systematized and compared one with another.

There is a different way of fuel engineering in European plants, where price of fuel is much higher than here. Fuel economy there is the basis of all steps. Combustion engineer not only distributes different kinds of fuel and supervises combustion, but supervises the design of furnaces, shows what kind of fuel is best adaptable for different processes and directs all operations which lead to the best fuel utilization.

When talking about average figures of fuel consumption per ton of semi-finished product in steel plants of the United States and that of European plants, and showing to the steel plant executives that we here use 2½# of coal per 1# of semi-finished product—whereas Germany uses only 1¼#-1½#—we nearly always encounter an answer that our fuel here is more than twice as cheap as it is there. Therefore, says the big man of the industry, we are even with the outside competition.

There is some sense in this reasoning, because following the law of diminishing returns, we cannot expect as much economies from the low-priced material as from the high-priced material. It must be mentioned, however, that the price of fuel in the United States has not yet reached such low levels, which allow any irrational handling of it.

There are many other things which can be said about general management of steel plants in reference to fuel engineering and one thing which is very important is rooted in the history of American Iron and Steel Industry development.

European iron industry was founded and managed by men metallurgically trained. Before starting the development of any part of the industry, these European men knew beforehand what they were going to build. The man in Europe, who knows little about the iron and steel industry, never will dare to tackle this kind of work. In the United States it happened to be a little different. They have been more daring here and experimented on many things without predetermining what will happen when the mill is built.

In the reminiscences of one of the most prominent iron masters of the United States, we may find that once he has built a very expensive mill and when it was finished he has found out that the mill was built wrongly. He and the proprietor of the mill did not hesitate a minute to tear down this mill and build a new one. Such things never happen in Europe. The plants there are scientifically managed, their general staff of engineers will pre-determine and calculate everything before a penny is spent. Paper and pencils are cheaper than brick, cement and iron. It is better to tear down several drawings than to tear down a mill.

There are some other interesting phenomena which could be observed in general management of iron and steel plants. These phenomena belong, however, more to the realm of psychology than of fuel engineering.

Somebody has put his furnaces on natural gas and the application of this kind of fuel became a fad. The use of natural gas started to spread faster than forest fire. What was the reason for that?

In many cases there was very little reason for such change. The only one excuse was that some company, because of local conditions, has visualized some kind of economy in such application and the rest of the managers just copied that without paying any attention to the real economy of combustion, to the quality of heating or to the effects of such kind of fuel on the finished product.

At this point, the fuel engineer should have come forward and presented his objections to such uneconomical and untechnical changes. It is true that in many cases of such changes fuel engineer was

not even consulted. The management has ordered him to change over night his furnaces from producer gas into natural gas. In many instances he has silently agreed with the situation. Sometimes he has welcomed such change because it was easier for him to supervise the furnace. Anyhow, the responsibility was taken from him and he felt safe.

A real fuel engineer, conscious of his responsibility and taking pride in his profession, should not allow such things to happen. He should show to the management, that his part in the metallurgical operation is as valuable, if not more, than that of the chemist and that fuel control room is as important to the steel plant as the chemical laboratory.

In most instances, however, that is not the case. In many plants fuel engineer is kind of a second-grade employee. He is only tolerated, so to speak, and he is not an equal part of a complete, well-rounded plant management collegium. As long as such conditions will prevail in the industry, fuel engineering will hardly be able to make any noticeable progress. Fuel engineers should fight to let themselves to be listened to, if they want to put themselves on the map of steel plant management.

Coming now to other parts of Mr. Dobrin's paper, which, to my mind, have to be regarded rather as a general survey and not a technical treatise, I wish to point out that in the part pertaining to the manufacture of producer gas, he omitted to mention that the observation and registration of steam saturation point of air-blast is one of the most important factors of gas producer management.

J. F. Shadgen: Gentlemen, I see everybody discusses the sales effort of the combustion engineer. Why should the man sell himself? Why does not the management consider him as an integral part of the organization? Why does the management offer resistance to an obvious problem of that nature? A man who has been hired to solve a problem, and as Dr. Foss says, he doesn't even get consulted. Why does this situation exist between the fuel department and the cost department?

It is just as if I would quarrel with my legs. I have to walk with them, haven't I? It seems foolish to quarrel with them. That is what I can't get through my head. Why does the management resist your sales effort? I would like to solve that puzzle.

W. P. Chandler, Jr.: I don't believe I have anything to say on Mr. Dobrin's paper. I was very much interested in it, because it starts back at the time a number of us started in the steel mills as steam experts. We weren't called steam engineers, but steam experts.

The development of the combustion engineer, as Mr. Dobrin has reviewed it, particularly when he broke away from the boiler house, where combustion was the prime requisite, and went into the regulation and operation of the furnaces, where the metallurgical facts are the prime factors in economy, has been most interesting and most gratifying.

F. E. Leahy: I think it was a very excellent paper, and I have enjoyed listening to it. There is one part of the paper where Mr. Dobrin recommends the keeping of records in order to more or less follow out the work as it progresses and have some means of measurement of the results accomplished.

That point is rather interesting to me, and I would even go further than that and say, Why don't we get these records he is recommending in such shape that not only interplant comparisons may be made, but intercompany comparisons may be made.

I think most of us have had this experience, when we go out and make a little investigation of our own to see how our operations were comparing with some of the operations in other plants, that we would be rather confused by the method by which they set up their results, so much so that direct comparisons were in many cases almost impossible. I think it might be worth while for the Association to start a little movement some time to get a better method of arriving at the final figures for measuring the performance in such shape that intercompany comparisons could be made.

H. B. Flagg: I wonder if I dare offer a suggestion in answer to Mr. Shadgen's query.

Isn't it because of lack of understanding, and consequently then because of lack of confidence? Is not steel plant combustion so specialized that the rank and file of steel plant operators do not appreciate the fine points involved, even up through the management? Take a mill supervisory group. Did you ever know a sheet heater who got to be superintendent of the sheet mill? Usually not, for the men who are given the supervisory positions come up naturally through the organization from the very start from clerical jobs, from turn foreman jobs, etc. The same principal applies right through, up to the general management. Men with such a background of experience rarely have occasion to become familiar enough with the heating art to be able to discuss a combustion problem with full understanding. Such men are compelled to depend on the judgment of others when faced with the necessity for decision on combustion problems, with the result that the decision is delayed at least until all interested persons are in agreement.

The thing that struck me most in Mr. Dobrin's paper was the manner in which he stressed the vital part combustion plays in steel mill operation today. It seems to me that the problem of making clear to both management and operating organization, the vital part that combustion plays in the operation, offers the greatest opportunity for a combustion engineer. He should be able to work out the principles involved together with the application and then so present the proposition to the management as to get a hearing without that element of distrust often encountered.

Mr. Dobrin brought out the fact that the efficiency of most heating furnaces is very low. This must always be the case so long as waste gases are allowed to leave the furnace at high temperature. Is there any reason why we should not have a continuous cycle, where we can burn enough carbon or other fuel to make up the actual heat that goes into the work and the necessary sensible heat loss in the flue gases from that amount of fuel? We have an approach to such a system in several processes on the market today.

Mr. Dobrin discussed gas burners at quite a length in a very pertinent manner. There is one thing I would have liked to have heard him do in connection with this topic. He discussed the operation of gas producers at some length. I wish he had discussed the application of raw producer gas

and the problems encountered in the use of this fuel through mixing burners. It seems to me that raw producer gas applications merit more discussion.

There is also the question of heavy fuel oil, which is a pretty live subject at this time. The present tendency to scatter refineries across the country in order to get away from transportation charges on gasoline is resulting in large supplies of heavy residues scattered over the country. The application of these residues to various heating problems is something we have to consider more and more as time goes on.

There is a question in my mind as to whether the market of fuel oil is going to be comparable to what it has been in the past. Under present conditions, fuel oil residues available are governed by the consumption of gasoline which is widespread and relatively stable. Such residues must be moved from the refineries in pace with the shipments of gasoline so that people who are in position to use them are in position to make attractive time contracts.

Geo. M. Coughlin: The practical side of metallurgical heat application as set forth in Mr. Dobrin's paper can briefly be expressed in three words and in the order of their importance: Quality, Quantity and Economy.

Regardless of the tonnage produced, without the necessary quality to that tonnage, the producer today is out of the market. Without economy in the cost of heat application even though the quality of the product is what may be desired, tonnage or production would be of little advantage to the producer were he to meet in competition the products of a plant where both quality and economy were in effect.

In these days of low cost and strong competition economy is a necessary item in the application of heat.

Mr. Dobrin's paper brings out that the average plant operator of today is too busy keeping his plant in operation and in repair to be able to devote much time or energy to the details of metallurgical heat application. Often he does not have the technical training required for making scientific tests or analyses of operating results. Again he does not have the time nor will he bother with delicate measuring instruments. The result is that often an instrument that would be of great value to the operator is condemned as impractical for steel plant conditions.

Then again the value of accurate records and analyses plays an important part. Mr. Dobrin pointed out that records, keeping the operator informed of his progress, are very helpful. Our plant for example will bear this out. Like a majority of fuel consumers, we started with a few measuring instruments which told us how much gas we had to pay for. The distribution to various units was nothing more than guess work. The operator realized this and made no attempt to correct a waste since he operated by rule of thumb and eye. Our first step to help this condition was to install some $60,000 worth of instruments and control equipment to give us control and an accurate record of consumption. From this a monthly fuel consumption record developed which told how each unit had operated during the previous month. At this time the operator became interested and asked for performance records of what was being done the previous week; then the day before. The result was a weekly record of fuel consumption, then a daily and in quite a few cases a turn record. A 24 hour B.t.u. balance maintains these accurate records. Here was a major step in the practical side of metallurgical heat application.

For now with an instrument with which an operator could control his furnace he saw the results not only in economy, but the effect on quality.

This opened up additional avenues whereby the combustion engineer could assist the operator in furthering these three major items, Quality, Quantity and Economy.

Mr. Dobrin's paper has pointed out the need of trained metallurgical combustion engineers. Most operators are very glad to welcome the help of a man especially trained for combustion, but it is rather hard to find men who are qualified by experience for such work, and therefore it is necessary to develop them before much progress along that line can be made. Men who do not fully appreciate the importance of the work and its wonderful possibilities sometimes hesitate to engage in such hot and dirty work and prefer the "white collar" job, but the "kid glove" efficiency engineer does not get very far in the modern steel plant.

Many of the metallurgical combustion engineers, in the plants today, have come up through the boiler house and can appreciate the comparisons set forth in the first part of Mr. Dobrin's paper, between the combustion engineer of a boiler plant and the metallurgical combustion engineer of the steel plant. Because of this previous boiler plant experience most of them find it hard to get away from the boiler plant viewpoint, that of quantity of steam and low cost of operation and set their eyes to a new goal which places the new term "Quality" first and then Quantity and Economy coming later.

Strange as it may seem, quality heating usually leads to the other two items, namely, quantity of product and economy in heat application.

Mr. Dobrin has pictured the job of combustion engineer as one with many angles and phases, and about the most important angle of this job is the human side of the combustion engineer.

He may have the technical knowledge of the world, he may be able to design the sweetest normalizing furnace ever seen, but unless he can sell himself and the ideas he presents to the manager, the superintendent and to the very furnace helper himself, his way will be stony indeed.

This is a day of job training in industry. The combustion engineer must take his part in this big work. He must make the mill "Heat Conscious." It is one thing to spot a leak and stop it, but it is another thing to keep it stopped. As long as the combustion engineer operates the furnace he can be reasonably sure that the type of heating is that desired, but the only way he can be assured that it will continue in that manner is to have the operator of the furnace thoroughly trained in his job of heat application.

I think a part of the last sentence of Mr. Dobrin's paper will bear repetition for emphasis. "The plant organization will learn to avail itself of this combustion department in the measure that such a department makes itself useful."

Harry Dobrin: In answer to Mr. Conway's question, I can mention any number of cases where on

account of poor heating of the skelp it is all scaled up and you have bad pipe.

I remember one particular firm in the Pittsburgh District had a great deal of difficulty in making pipe, and while it wasn't very large size pipe, half the pipe would turn out what they called "raily." That means it was just good enough to use for railing and was sold for less money than a second. It is really a poor pipe.

It is so obvious that it depends on the kind of heat they carry in the furnace. Sometimes they just can't weld at all. If the heat is right the burnt gases come out with a certain golden copper color. If you don't get that sort of color in your furnace, you will find the welding job isn't well done.

I would have been glad to have heard some of the men discuss this, like Mr. Leahy, who is quite familiar with the multitude of causes, as to why bad pipe is made, which can be traced through to poor combustion. You may carry excess air. If you carry too much air, you are not going to get a good welded pipe, and neither will you if you carry an insufficient amount of air. If you carry too much rich mixture, the chances are you are not going to develop a high enough temperature to be able to do the welding job.

Does that answer your question?

M. J. Conway: You have answered my question in part Mr. Dobrin. What I have in mind is that providing the furnace temperatures and atmosphere are correct, that weldability is largely a function of oxides in the skelp. Rejections due to surface defects through imperfect heating conditions even though the pipe weld is alright is really the subject of my question.

Harry Dobrin: That may be so, of course. The scope of my paper and all the arguments are predicated upon conditions which are traced to the fuel. It is true there may be a flux. There may be also metallurgical conditions. There may be chemical conditions which have to do with bad heat. I have been saying right along that very often a poor quality results from conditions or causes other than the heat application. But I am saying, let us assume for the sake of argument that the other conditions, the chemical and metallurgical conditions, have been cared for, but still in all that leaves bad quality in the product, due to improper adaptation of the application of heat, because after all, heat application is one of the most temperamental things there are, almost as exacting as welding. You have to get the proper conditions, not too much of an oxidizing mixture and not too much of a reducing mixture. You have to limit it to a certain point.

So, for this reason, we begin to see why the steel industry has taken to heart the idea of combustion control. I believe one of the greatest benefits that can come to the welded pipe makers is to begin to seriously avail themselves of the value of control, especially to the proper ratio between gas and air. I am sure they can straighten out a good many of their troubles which can be traced to heat.

I have had a number of talks with Mr. Leahy and others about these records for comparing fuel economies and fuel practice from month to month.

Some companies have standardized on these things, and the reason I didn't feel that it was the proper thing to bring an example or to publish one was that these companies usually have spent a good deal of time and energy and money to develop something for themselves.

But briefly, assuming that you have any number of heating processes across your horizontal column, the vertical column opposite each heating process would carry the fuel average for that process for the per ton average for the month. We will say you are running across—January, February, and March, April and May, if you get hold of the central line you can begin to see the progress you make, whether you are going up or down, at a glance.

This is not of such great importance, gentlemen, for the operating offices, but I have found from experience that it is a very, very excellent way of interesting the executive management in what the combustion department is doing. When the executive management each month gets a statement showing each heat process, each type of furnace, and are able to see at a glance whether they have gone up or down, then this is a means to bring the combustion department's work very forcibly to the front, to the management.

In fact, I have been surprised many times in some organizations where as a consultant I have observed such a system. Usually I have got them into the habit of having such a job presented along about the tenth of the month. Very often no less than the vice president of the company would call me up, "Mr. Dobrin, where is the fuel record for this month? I am going out of town, and I would like to see it. Can't you manage to get it for me a day or two sooner?"

In such organizations where the executive management, the men who have the purse strings in their hands, are so interested in the progress of work from month to month, you should be able to secure the necessary appropriations. You will never be able to effect real economies without getting the organization to open up a little and be liberal in their expenditures.

Now, when the combustion department has succeeded in securing the money, one of the most important things to do is to be very careful to show the results, because it is fatal to crowd the management for money and get money, and then make a poor job of it or turn out a furnace that isn't producing and isn't working properly. So the most important step is to get the results so that it will be noticeable on the fuel.

After they have spent the money, they watch that particular item. If you have gone up, it is too bad for you; you are not going to get any more money. But if you make one good job, another good job, and a third and fourth good job, it will surprise you how quickly they will give you more money. They will say, "Do you know what you are about?"

"Yes, sir."

"All right, we will let you have it."

It is part of the work of selling the combustion function to the management.

Mr. Flagg tried to explain the psychology of the aloofness of the management in organizations. We always are afraid of the unknown; we try to steal away from the unknown. The same must be also said of the combustion engineers. I have observed a good many of them, in the course of my practice. They will seek the line of least resistance. If it isn't

a certain kind of thing they have to live close up to, they are inclined to steal away from it, or they are inclined to let somebody else put it in for them. That is what Mr. Coughlin meant when he said, "You must live right up close to your work."

How many of you will tackle aviation? You know that is a very, very vague thing in your minds. Many other things are invisible—radio, for instance. When you come to the application of heat, there is something in the psychology of a man's mind. The operator doesn't know anything about it, and he is afraid to admit he doesn't know anything about it. If you are familiar with your job and go into the organization and go to the heater, and don't scare him but talk to him with plain common sense, and explain to him in his own language what this thing is all about, you will accomplish a great deal.

The educational work has to be carried on right through the organization. It is a development. The only reason they are not sympathetic with the work is because they do not understand it. But once they begin to understand, once they begin to see the results, and once you have tried to sell him in a subtle manner and not tried to overawe him with your knowledge of the subject, you will begin to see an improvement.

In one case I had as difficult a job to handle as I have had in the course of my practice. I was so humble I put on overalls; I didn't want to overawe the organization. I didn't want to scare them. I just came in as a workman who was supposed to know his job. In a short time I won them over. They didn't know I was a consultant. They thought I was just a helper, an assistant. I even carried instruments. It was a matter of policy, the psychology.

The function of the heat engineer had been so neglected in that place, that it was necessary to do about 98½ per cent human engineering and only about 1½ per cent combustion engineering. The problems to be solved were very simple. There was nothing deep about it. It was more to overcome that invisible resistance.

Mr. Flagg asked about the producer gas operation. I didn't think it would really enrich the paper's value by going further. We all know that there has been quite a solution found, especially for the low temperature application, in the use of a mixer type burner. I wish Mr. Flagg would have added or supplied the necessary information, because I know that he is very well suited to do it. Mr. Flagg well knows the very fine application and the very nice results that have been had by the application of producer gas for these very low temperatures.

In fact, some years ago in the tinplate industry, where they have occasion to use a temperature of from 1000° F. to 1050° F., they introduced a burner firing from the end of the furnace into a conduit. That conduit was running the whole length of the furnace, and all along that duct were holes for the emission of the gas.

That has been a very successful way of producing producer gas by means of a mixer type burner, where the oil is introduced with the gas. It burns like a candle. Very often when the burner is well on and the conduit is hot, the combustion looks like you were burning condensed fuel, coke gas, or natural gas.

In burning some of these fuels, for low temperature work especially, you must use it in an indirect manner. You can't take a producer gas burner and release it right out in the open and expect to do low temperature work. You must do it indirectly. You must burn this gas out of a mixer type burner into a duct, and just permit the burnt gases to come out.

Discussion

Open Hearth Furnace Control†

By M. J. CONWAY*

J. F. Shadgen: I feel that I am not really competent to tackle the subject, in particular, because this afternoon we are going to have a special discussion on equipment.

I am not an operator; I am connected with a control manufacturer. Obviously everything I will say is under the shadow of suspicion, to say the least.

There is one thing I want to make plain, and that is that the **Reliability** of the operation of the control equipment is perhaps the most cardinal feature that has to be made good by the manufacturer. If the equipment is put in and does not work reliably, continuously every day, every hour, every minute, the confidence of the operators is going to be shattered and it will require months to rebuild the damage a five minute breakdown has created. That part is a very difficult part to solve—a continuous, reliable, 100 per cent equipment which is practically foolproof.

The concern with which I am connected has over forty installations operating more or less satisfactorily. You see that I am not very sure of myself, because there are so many variables, there are so many difficulties to solve independently in each plant, that in all fairness to the subject, it would take another year or two before we are out of the woods.

Dr. F. F. Foss: An explanation of what was said about the ability of manufacturers' fuel engineers to sell their ideas to the plant management, could be found in my previous remarks on the status of the fuel engineers in iron and steel industry.

Taking into consideration the described position of plant fuel engineer, it is easy to understand why plant managers, who very seldom have a deep knowledge of combustion problems, listen more to the manufacturers' sales engineers, whose interests are

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* Fuel Engineer, Lukens Steel Co., Coatesville, Pa.

concentrated in the direction of larger sales of their product, than to their own engineers. These sales engineers are hired to use their ability to sell in preference, so to speak, to the fuel engineering. The plant fuel engineer, on the contrary, specializes exclusively on engineering and does not think of a way to sell his ideas to the management. That is the reason why the plant fuel engineer is not listened to. In the eyes of the management, he is not supposed to know the latest fad in fuel application.

Coming now to Mr. Conway's paper "Combustion Control of Open Hearth Furnaces," I wish to say that this paper contains valuable information on different phases of open hearth operation. With all due respect to the figures contained in the paper and deductions made from them, I still doubt whether this paper has shown the advisability and adaptability of this so-called "combustion control" in preference to other improvements of open hearth furnace, which have been delayed for such a long time.

As we all know, the open hearth furnace is an instrument of very low efficiency, to which many elements of furnace design are contributing. The open hearth furnace's design actually belongs to the past century. The "automatic control," as it is advertised, is a very interesting item which may improve the conduct of the open hearth furnace, but by no means is it an ultimate solution of the proper open hearth operation.

First of all, it should be emphasized that all these arrangements, presented up to the present time, are not "automatic" and secondly, they do not "control." If there is a need of a nickname, I would call these arrangements "attention caller" or "temperature alarm clock." I am afraid that if we are going to stick to this fad of "automatic control," which is spreading around all steel plants of the country, we may lose sight of many more important points of the open hearth construction. That may delay the development of proper fuel combustion, rational burner construction, correct proportion of checker chambers, cooling devices and so on.

There are several points in open hearth operation to which there was very little attention paid up to the present time. Take for example, the problem of moisture content in products of combustion and their influence on the spalling of bricks inside of the furnace, particularly that of the roof.

We, here, are satisfied with 250 to 265 heats on one roof. In Europe we know that the average number of heats on one roof is from 500 to 600 and roofs standing 1000 heats are not exceptions. The average consumption of silica-bricks per one ton of steel in the United States is between 50 and 60#. In Europe it is exactly one-half, amounting to 15 kilograms. That is one of the items which may seem to be small, but is very important when the question of operation's efficiency and costs of conversion is taken into consideration. This problem stands in direct connection with moisture content in the fuel, in the air and the products of combustion.

There is another problem in open hearth operation and that is water cooling. We, here, put water in every place of the furnace which we could only take hold of. In Europe water cooling is used very sparingly and in many instances, is not used at all and still the brick consumption there is only 50% of ours.

Next comes the question of the proper size of checker chambers, size of the checker brick and amount of surface needed for transmission of heat. It is safe to say that three-fourths of furnaces in the United States are working highly unsatisfactory on account of the fact that the regenerative principle is wrongly applied.

Having all this in mind, I wish again to emphasize that putting too much stress on the misnomer "automatic control" may befog actual problems standing before us in open hearth management and obscure more important real problems of open hearth furnace construction. I welcome the work of application of scientific instruments for the purpose of observation of different phenomena during the process and alleviating the management of the furnace, but I warn against promises and expectations that "automatic control" will be a panacea from all open hearth operation troubles.

H. B. Flagg: In reference to what Dr. Foss said, I have had occasion to observe a situation which applied. I remember one furnace that ran behind the rest of the shop, consistently so, day after day, week after week. There was the same setup on the furnace, and as far as life was concerned, it should have made better production than some of the others. Finally the three first helpers were moved off that furnace and were placed with other men. The furnace snapped out immediately and ran along with the rest of the shop.

The inference was that some peculiarity of operation common to these three men was affecting operation adversely. The conclusion is that any agency which will help eliminate such influences is well worth anything that it costs.

W. J. Harper: I have nothing further to add. I don't think increasing the control on the furnace is going to cut fuel practice. I think there are a lot of other things to be considered that would cut fuel costs 10 to 20 per cent. I think first you have to start on the insulation of checkers and the air filtration before the automatic control will be satisfactory.

In regard to the point Mr. Flagg brought out, about the engineer not being able to sell himself, I think the reason is, he doesn't talk the language of the management. You don't want to go in and talk to the management about the saving in B.t.u., what they are interested in is the saving in dollars per month.

George M. Coughlin: This question of furnace control is somewhat similar to the fact that you buy a new car and expect very good performance out of it, but in these days of high compression engines, you will find when you buy that car you put Ethyl gas in it. You don't run around on white gas. In other words, the fact that you have the control, as Mr. Harper says, is not enough. I think that too many of us have tried to make our jobs easier by buying things we think are going to help us, without doing other things that are within our control. We go around and preach fuel economy, but do we practice it enough? Do we do all we know to do before

we try to see what the automatic arrangements will do to help us?

Mr. Harper talked about the insulation of checkers. He is right. What are we doing in our furnace design? Of course, the standing joke among the open hearth superintendents and those who know them is that no furnace is ever built back with the same lines that it had at the beginning of that run. They are always changing and always hunting for betterments. I think they are right, but whether they can tackle the problem to get enough information during the operation of that run so they can intelligently build it back along new lines, is another question. There is a job for the furnace engineer.

At the present we have no automatic controls in our Ashland Division plant, but we do have control. We have intelligent control. Mr. Flagg pointed out the human element. You have to make some arrangement to take care of that human element. One of the best things, as I emphasized in my previous discussion, is the absolute training of those men. Before you can train them, you have to know a lot about it yourself. You have to get in and work with them. Mr. Dobrin says he went in with his overalls on. You must have the overalls.

We have done what we know to do in our plant to better our furnace conditions, and we have bettered them as time has gone on. We have increased the tons per hour 30 to 40 per cent and knocked off the B.t.u. that much, but there is still a whole lot to be had in automatic control.

When we meet here, ten years from now, we won't talk about automatic control. There will be something else. It will be a common, ordinary, everyday occurrence; we are all going to get automatic control. Whether it will be control from automatic proportioning or from the products of combustion of the furnace, is still a question, but it is going to be settled within the next few years. It might be a combination of the two. Personally, I believe that will be the case. We are going to come to automatic control not only on the open hearth—of course, in the open hearth you use 40 to 50 per cent of the fuel in your plant—but we are going to come to it, as Mr. Dobrin says, on skelp furnaces, on galvanizing pots—a lot of us have—and we are going to come to it on all our furnaces. You men who are selling automatic control, don't spend all your time with the open hearth superintendents.

G. D. Conlee: For the last few years, I have been a spectator or interested watcher of the open hearth furnace process; as a consequence, Mr. Conway's paper has been very interesting.

Right now the question of open hearth control is very much up in the air. I don't doubt but what automatic control will work satisfactorily in some cases, and in other cases, the hand control, with instruments for guidance of the operator will be entirely satisfactory. The factor that will have a large effect on open hearth operation is the fact that the open hearth furnace as built at present is a poor sort of heat container. The air leaks in and the gases leak out and neither flow is a constant rate from day to day. While automatic control may reduce the work of the first helper, it will not be the determining factor in bettering combustion efficiency.

The insulation of the furnace is important. It should be as nearly air and gas tight as possible. Bringing it up to a condition comparable with that of the modern boiler is going to help a great deal.

I concur with Mr. Coughlin in the belief that ultimately some sort of control which will take into account the composition of the gases over the bath will be developed.

W. P. Chandler, Jr.: The open hearth control is a thing I have been very much interested in for some time. There are three main factors in the control that I would like to just mention. One is the draft control; one is the air control; and one is the reversing with temperature or some temperature control.

A great many people have used the first two—air control and draft—with sometimes good results and sometimes mediocre results. It has been brought home to me, the longer I spend with furnaces, that there are usually outside factors that we don't appreciate, coming into the picture, that change the operation.

Mr. Coughlin just mentioned one of the points that is of prime importance. A furnace must be insulated. When I say insulated, I mean against air infiltration, not so much against heat loss. A control cannot function if you have a sieve for it to work in.

An elaborate test made recently on an open hearth furnace showed that as much as 42 per cent of the air used for combustion didn't pass through the checkers at all; it was infiltrated. Yet this was on a furnace in which excessive care has been used to eliminate air infiltration. You can't expect a piece of apparatus placed on a furnace to do something that isn't possible. You can't expect results when the equipment on which the control is to work is not fit to receive it. There are a great many people who have had sad experiences with control equipment who should not blame the control company at all.

Generally speaking, better results can be obtained by the use of the draft control, which developed originally in the boiler industry. If we look back into the steam industry and see the balanced draft system and later the elaborate system of control, all gains in themselves, we should have a picture of what will happen in the furnace.

At the present time there is a great deal of discussion about control, and the open hearth furnace is ripe for draft control. A great many people have used air control. There is no question that air control will be of real value in the future, but a lot of people at present don't appreciate the value of air control, particularly as far as the first helpers on the furnace are concerned.

I believe the draft control is absolutely necessary. I believe the temperature control should be worked out so it functions the way some of the furnaces have functioned that I have seen operating with it. And the air control should be worked down to the point where it really will function and be foolproof.

W. R. Paulsen: I think the great trouble is that most people look at combustion control as the final word in stead of the starting point. In other words, combustion control eliminates two of the doubtful items. One is the combustion air and the other is the draft. If we have these under control, the amount of infiltration through the checkers and

other parts of the furnace can be determined and corrected.

L. Ellman: There isn't very much that I desire to say at the present time in reference to the application of flat roofs to open hearths except that we have two installations at the present time. Due to the present business conditions neither one of the furnaces has been operating at a sufficiently steady rate of operation to obtain accurate data concerning the relative roof life between the flat suspended roof and the ordinary sprung roof.

It is our opinion that eventually the application of the flat roof will be worked out in conjunction with the port construction.

M. J. Bradley: I don't think there is much that I have to add to the paper. I glanced over it rather hurriedly, so I am not very familiar with the contents. Apparently the points I had in mind have been pretty well covered. There are a few points possibly on which we would like to have a little more information, but I think they may be brought up this afternoon in the further discussion, so I won't bring them up now.

H. A. Lopez: While discussing draft control, it is opportune to mention the fact that in a good many furnaces operating on natural draft, there is insufficient draft particularly towards the end of the campaign. With increased infiltration and clogging up of the checkers towards the end of the campaign, natural draft results in decrease of furnace capacity. With mechanical draft, sufficient draft can be had at all times.

Natural draft has always meant limitations in the design of the regenerators. With mechanical draft, the design of the regenerators can be altered with the assurance that increased resistance will be taken care of by the induced draft fan. This is true in the case of multiple pass checker work or stove type regenerator.

Two methods are now employed to provide additional stack draft; the ejector tube and the high temperature induced draft fan. When the flue gases are handled directly through a high temperature induced draft fan, the horsepower consumption is less than one-half the horsepower required when using an ejector.

The first installation of our high temperature induced draft fan has now been in operation for over six months, with satisfactory results both from a mechanical and performance standpoint.

A Member: I have no discussion on Mr. Conway's paper. Like some of the others, I haven't had time to thoroughly read it.

I would like to ask Dr. Foss a question regarding the moisture content of producer gas. He spoke of the effect on refractories. What means have you taken to control that action, Dr. Foss?

Dr. F. F. Foss: There are several ways of moisture control in the furnaces. When producer gas is in question, the moisture control can be conducted as it is shown in Mr. Dobrin's paper. It consists in the control of steam addition to the air and in seeing to it that the steam is completely decomposed before entering into the gas, that only a proper amount of steam is added.

My general idea is to have the least possible amount of hydrogen in the furnaces. After combustion, hydrogen gives water vapor, which is most deleterious to the refractories. Therefore, the least hydrogen is in your gas, the better your refractory stands. For this reason, I am not in favor of using coke-oven gas for heating of iron, except in cases where there is no other outlet for the use of this gas.

In regard to the statement of Mr. Conway, that he has not noticed any ill-effect on refractory after having changed from compressed air to steam as an atomizing medium, I wish to mention that it would be very interesting to have some figures substantiating such statement, as general observations sometimes are not quite reliable.

It is scientifically proved that excess of moisture content in products of combustion affects the rate of refractory spalling. It is quite possible, that in this particular case, quoted by Mr. Conway, the service of refractories, when air was used as atomizer, has already been rather low and the change to steam could not produce any worse effect.

L. Rumford: With specific reference to this paragraph headed "Energy Requirements" on page 293, I am interested in whether Mr. Conway made actual measurement of the temperature of the in-going air at the entering of valves, entering checkers, leaving checkers, in uptakes, and leaving ports?

I am also interested in the construction of the type of thermocouple that he used for that work.

E. A. Vierow: We have heard a lot about combustion control. I am wondering if the combustion engineer himself is as yet in position to avail himself of all the possibilities of this equipment. For instance, are we actually sure of what we want in the open hearth furnace, as far as combustion goes, the type of fan, the excess air, and things like that?

J. F. Shadgen: I can aswer that question. First you have to solve the quantity measure. You have to put the number of B.t.u's in. Your control does that first. It puts the cash register in. You may be 2% off or 3% off, but at least you know when you are off.

After you have solved the quantity equations, it is necessary to solve the flame temperature, flame atmosphere and flame characteristics. All we try to do at present is solve the first equation, and then we need the co-operation of the engineers to solve the second one. But you have to make a start.

I make no claims about the infallibility of the quantity equation, but obviously it is the first one to be solved.

Of course all the ducts must be closed and not be sieves, as Mr. Chandler says. You would not take a bath in a sieve, because the water would run out. The same thing is true when the ducts are leaking, no matter how much you measure them. If they leak after you have measured them, you are simply helpless.

Combustion control is merely a tool we use to get things straightened, that should have been out before. Combustion control brings to the management the necessity of correcting these things. Control to me is just like a steam engine. The cylinder is there, the piston is there, the steam is there; what you have to control is the right proportion and the right amount of steam to either side of the cylinders. Co-ordination always pays for itself.

Harry Dobrin: Before Mr. Conway summarizes

and answers the questions that came up about the paper, I wish to state that controls, regardless of their individual merit, or regardless of which particular kind of control you may want, if they serve no other purpose than to standardize an operation and free you from the human element, they have served a purpose.

The control keeps you from testing around. Very often you want to find something, and when you have found it, you don't know whether you have found it or not. It is always elusive. Suppose you have established a certain condition that you want. How are you going to keep on repeating it a thousand times out of a thousand? You will try to find it, and maybe you will and maybe you won't. You can see how you are dependent on your own element.

An instrument in any control will enable you to get away from the human element. Without control, without instruments, you are always in the hands of the human element.

These three men that you moved, Mr. Flagg, from one furnace to another were probably good men, but the chances are that was a poor furnace, for if it had had the same kind of arrangement of the control as the good furnace, you would not have had to do that. You would have been able to determine your standard conditions, because you would have had one universal language. All you have to do is establish your condition. You can duplicate the condition which is favorable by means of control, and you can consistently eliminate the destructive element which you don't want in there.

M. J. Conway: Mr. Shadgen's question had reference to the reliability of the equipment, and I assume that he means the average life. We may obtain five, ten, or fifteen years of useful work from some types of control equipment. My estimate is an average life of ten years.

Dr. Foss brought up the point of making improvements in design and operation of furnaces, before adapting control. The installation of control equipment on open hearth furnaces automatically brings about the improvements mentioned by Dr. Foss. The installation of combustion control necessitates tight furnaces free from air infiltration and the improvements made along these lines during the past two years in plants where control has not yet been applied is due in part to the improvements made by control in other plants. In other words it has put "salt on your tail."

Dr. Foss also brought up the point of moisture in producer gas and its effect on furnace refractories. It is my opinion that with the present means available for the control of the moisture fed to the producer for the gasification process, that little or no bad effects should be noticed from the moisture in producer gas within the range of good gas house management. I may say in passing that we recently changed from compressed air to steam as an atomizing medium on an oil burning open hearth furnace without noticeable ill effect on the refractory and this would at least mean the addition of 80 lbs. of steam per ton of ingots.

Mr. Flagg's discussion brought out the necessity of education and direction in the operation of an open hearth furnace whether or not a control is installed. We are all prone to sidestep this issue but the fact remains that furnacemen as a class are improving, not entirely from contact with each other, but from information supplied by their foremen and superintendents and the results are worth while. One of the first things necessary after a control apparatus has been installed is a thorough explanation of its function to the furnacemen. This in itself is a worth while feature.

Mr. Harper explained that the combustion engineer should have a dollars and cents point of view as well as a B.t.u. point of view. He has. I believe I led up to that point in my paper by talking of savings in money. Dollars and cents are used in our language to our executives, but B.t.u.'s are the fundamentals to which we as engineers resort when dealing with causes. Woolworth may make twenty per cent profit but not by selling four pennies for a nickel, rather by selling an article which cost four cents to hand to the customer. His success is in crowding the greatest article value into a nickel; our success comes from crowding the greatest number of usable B.t.u into a nickel.

Mr. Coughlin points out that they are doing very well by having stopped air infiltration and generally tightening up their furnaces. This statement bears out what I have pointed out previously that this movement of control installation has had its effects even in those plants whose engineers are not yet sold on control.

Mr. Chandler stated that control cannot function properly on a leaking furnace. It is obvious that the installation of control calls for a tight furnace throughout the entire campaign. With the average control installation, a set of recording instruments is usually attached which record the fact that the furnace is leaking, and we as combustion engineers in selling ourselves, cannot do better than sell to our executives some of these schemes of obtaining greater economies. Instruments without control are good, but recording instruments with control are much better.

We owe to the control the opportunity of being able to purchase those recording devices which have been our dream for years, but which were very difficult to obtain without control. Without these recording instruments, we cannot tell what is happening on the furnace continuously. Very few of us care to work night and day for several days to record furnace happenings, yet continuous records are certainly necessary when analyzing furnace operation and design defects.

Mr. Paulsen points out that control may not be the final remedy. In its present form it may not, but, in the murder of open hearth fuel and refractory waste it is certainly an accessory to the fact.

Some of us have the attitude of the Two Black Crows, "Even if it was good, we wouldn't like it." As bad as it may be in its present form, it is a step in the right direction and improvements will not change the basic design.

Mr. Rumford asked me a question relating to data on page 293 of my paper. These data were obtained from Richards and other engineering references. Thermocouples used were the aspirating type. If I have not answered sufficiently Mr. Rumford's question and he cares to restate it I will be glad to answer further.

Dr. F. F. Foss: I would like to add a few words in the way of explanation and state again that I am

not against the use of instruments to observe and register different phases of open hearth operation. I tried to make plain that all that has been offered up to the present time as "automatic control" does not "control" the open hearth process and is not "automatic."

There are different instruments installed on the open hearth furnaces for the use of operating men, which may alleviate their work to a certain extent. Such instruments, when they are properly made and properly installed, I welcome from the bottom of my heart, but if this misnomer "automatic control" is put before the higher executive, who has to approve money expenditure on such installation, he may think that in buying this "automatic control" he has acquired the last word in furnace equipment, that the open hearth operation has received its ultimate solution and that nothing more has to be done to the open hearth furnace.

Actually, however, by installation of several recording instruments on the open hearth furnaces, we acquire very little control over the process. We are just only beginning to bring to the surface all weak points of open hearth furnaces, which require very close attention, extensive observation, deep thinking and new expenditure of money. All this will be needed as long as the present design of open hearth furnaces is not perfected to high degree of efficiency.

Discussion

Electrical vs. Mechanical Devices Used In Combustion Control of Open Hearth Furnaces

M. J. Bradley: The best method to modernize the open hearth furnace is to replace the mechanically operated equipment with electrically operated equipment. The general adoption of the electrically operated units is evidence that the personnel of the open hearth shops appreciate the advantages. Electrically operated charging machines, charging floor cranes, pit cranes, bottom making machines, reversing dampers, draft fans, etc., are standard equipment in many open hearth shops. Further, the measurement of temperatures in the open hearth system depends entirely upon electrical devices. With all this in mind, it is not difficult to see why electrically operated control devices for open hearth furnaces are meeting with such favor.

The control of fuel and draft is only one phase of complete combustion control on the open hearth furnace. Another important phase is the rate or velocity of the combustion reactions and their effect on the character and temperature of the flame. In fact, all the factors contributing to the total heat input to the furnace should be included. Recently Messrs. Henry and McLoughlin published a heat study on an open hearth furnace in which they state in part—that of the total heat imput to the furnace 72.7% was derived from the fuel supplied through the burners, 16.6% was obtained as preheat in the air for combustion, and that 10.6% was obtained from the chemical reactions taking place in the bath.

It is absolutely necessary to preheat to a high temperature the air used for combustion in the open hearth furnace in order to produce a flame temperature high enough to melt low carbon scrap or to heat the steel to the temperature required for tapping. This is evident from the fact that the products of combustion together with the nitrogen from the air used, plus a small percentage of excess air, leaving the hearth at approximately 3100° F., carries along as sensible heat, the equivalent of the gross calorific value of the producer gas used for fuel.

The regenerative system has always been used as an operating means to at least partially control combustion. The first helper invariably holds the fuel longer on one end than on the other when he wishes to balance the furnace in order to obtain similar flame conditions from each end or when he wishes to heat the bath more on one end. The reversing valves, dampers, and air saucers, therefore, play a very important part in the practical operation and control of the furnace. Reversals can be made more rapidly with electrical equipment than with mechanical equipment.

For example, it required from 55 to 58 seconds to reverse an open hearth furnace on which the mechanical reversing levers were not centralized. It required 11 seconds to make the reversals automatically after the mechanical equipment had been replaced by up-to-date electrical equipment. Assuming that the average time between reversals is 15 minutes, the fuel was off the furnace, when mechanically reversed, 90 minutes daily, while after the electrical equipment was installed the fuel was off only 18 minutes daily. In other words, with the automatic electrical control the fuel was on the furnace 1 hour 12 minutes more each day or approximately 80,000,000 B.t.u. were being supplied to the furnace where previously only radiation losses were taking place (16%).

Many open hearth furnaces, using mixtures of liquid and gaseous fuels, are being reversed automatically by the temperature difference method. (The term automatic is used because the motivating force, which starts the reversing sequence, comes from the gradual change in electromotive force generated by the hot junctions of the thermocouples connected differentially and located in the regenerative systems).

Electrically operated equipment has been developed to carry out the reversing steps in exact sequence. As each step is completed it makes a positive electrical contact starting the following step. Electrical response is immediate so that the electrical units do not require to be centralized but may be installed where required. Thus, the electrical devices speed up the operation, are flexible and reliable, and may be made sufficiently rugged to successfully meet the operating requirements.

A Member: Gentlemen, I have had a little experience with combustion, both with fuel boilers and with the open hearth. The whole principle of this automatic control seems to me to be what we experienced with boilers about fifteen years ago, in trying to find out the fundamentals that we wanted to do. This is the most important thing. To find out the fundamentals you have to find out what you are doing. Nine out of ten open hearth operators don't know. Their meters are usually wrong. I have found that to be the case. They really don't know even their B.t.u. input per ton of steel. If you don't know what you are doing, you can't make an improvement, if you don't know the fundamentals of combustion principles. And they apply to an open hearth furnace just as well as to a boiler furnace. You can't properly improve combustion conditions, if you do not know what you are doing.

Most of the combustion controls have been played with by men—I am not talking about manufacturers, but operators,—who really don't know what they are trying to do, excepting by guess and by gosh. The old boiler operator did pretty well by looking into his furnace and regulating his dampers, but the more the combustion engineers will have the knowledge of the fundamentals of these open hearths, the better results they will get.

There was one thing in Mr. Conlee's talk with which I disagree. He says that the control of combustion in boilers is rather simple. Theoretically it is simpler in an open hearth, where you can actually measure the fuel and air. In the boiler you can't very well measure the fuel. Your control system usually works from what the fuel has done, in other words, your steam flow or your gases.

Another point I want to mention is the gas regulation in an open hearth. The draft differential, draft pressure, is extremely low, and the instruments that I have played with on boiler work will not work in an open hearth. I have played with the other type, too.

The third point is the location of the draft tube. That is extremely important.

Another thing I want to bring out is the complicated adjustments on most of the controls I have seen. To get them working seems almost impossible, and to keep them working is even more difficult.

George M. Coughlin: Representing the operating group, I think that we fellows have been rather lazy. We have sat back in great calm and allowed the manufacturers to hand us something, whatever they wanted to give us. I think we have made a very sad mistake. The manufacturers know a lot about our processes, but they don't know as much about our needs as we ourselves, if we really sit down and analyze the condition.

These gentlemen have had a very interesting warming-up period. You might call it a training camp, getting ready for the battle royal, which is to come later. They are used to meeting with one another in general competition, and I think possibly the battle might not be interesting enough to us unless we throw some new factors into it. Therefore, I want to get in a few words to give them a chance to develop some new blows before the heads start to fall.

This really is for the benefit of the manufacturing representatives. The operators don't need to listen.

When Dr. Foss said this morning that automatic controls were neither automatic, nor did they automatically control, he spoke some thoughts that were pretty well established in my mind. In fact, I heard a well-known engineer say at another meeting, something that is applicable to that. He said that it reminded him of Welsh rabbit; it was neither Welsh, nor was it rabbit; it was just a hunk of cheese.

That is possibly putting it a little strong, gentlemen, but it is the operators' fault we haven't got what we want. An earlier speaker said this afternoon that he liked electrical devices because electrical devices were his business. I think that all of you fellows in the open hearth automatic combustion control manufacturing are just in the same boat as the Republican voter, who votes that way because his father and his grandfather did.

The first open hearth automatic combustion control device in the market was on ratio control, and all the rest of you, like a bunch of sheep, followed the lead. I think it is time to think along other lines. You have overlooked the fundamentals of combustion in open hearth furnaces. Years ago the CO_2 recorder was put on the boiler plant, not to tell how much CO_2 was in the products of combustion, but to indicate to the engineer how much oxygen was in the products of combustion. It was an easy way to do it.

Really what we are interested in, as Mr. Dickey pointed out today, is how much oxygen, excess air, is carrying heat out of the stack. You make your savings on that. You all talk about that. You will reduce the fuel bill 10, 12 and 15 per cent. Some have made exaggerated statements.

The operator controls the B.t.u. input to a very large extent. He does not control the B.t.u. that comes off in the shape of combustible gases from the bath.

Not only one of you, but several of you—and you all meant to say it although some of you forgot—have manual adjustments on your automatic controls to give variable air input to the furnace. Why have you that adjustment? So the first helper can adjust the air supply to take care of the unburned gases from the bath. But how is the first helper going to know how to adjust that supply? You are just putting him right back to the point where he was without the automatic combustion control. You remove the automatic feature immediately if you cannot control the first helper's judgment.

To prevent any misunderstanding, I want to tell you I am sold on open hearth combustion control—so-called automatic control. It is a whole lot better than the way most of us are operating open hearths without it. I don't want you to misunderstand me. I am trying to emphasize a point I think we have all been overlooking.

Mr. Dickey grew alarmed about considering the

proper sampling of gases from the hearth. If any of you have tried it, you know it is a hard job. So to establish myself as an authority on that subject, I want to tell you that I have been spending the last five years and a large part of the American Rolling Mill Company's money trying to do that very thing. The men who had been in the boiler game did it long before that.

They found they got sufficiently accurate results if they took a sample of the gases at the exit of the combustion chamber and in the large stream of gases away from points of air infiltration. They were not looking for laboratory results, they wanted just a practical sample of the products of combustion. For a while they got theoretical about it and discussed multiple orifice sampling lines, dilution with infiltrated air, eddy currents and all the things the open hearth men are beginning to discuss today. Finally they decided that if a sample was taken at the exit of the combustion chamber and in the center of the volume of discharged products of combustion before they could be greatly diluted with infiltrated air they would have a workable sample. That is what they are doing today and look at their boiler efficiencies of 80 and 85 per cent.

But strange as it may seem in spite of what Mr. Dickey says, all of these open hearth automatic combustion controls get initial and final setting by taking a sample of the products of combustion. If the samples are wrong, they have the combustion controls set wrongly. Each furnace has a definite amount of air supplied to it for combustion. Part of it comes in through the fan or the air saucer; the rest of it leaks in through the leaky furnace, through the checker roof, through joints in open hearth flue system.

I hope some day we will find an engineer to design an open hearth furnace that won't have bad leaky joints. You might have just as tight a furnace as you can have when you start the campaign. You will run some draft and flue gas analysis surveys of the entire flue system and make your records; then three weeks later, no matter how well you use the mud gun in spattering up the walls, you will find you have 10 or 15 per cent additional air leaking, and it grows and keeps on growing. How are our present automatic combustion controls going to take care of that? How do we find it is there? We sample the products of combustion! Then we change the setting on the ratio control.

You can talk to the blast furnace operator or the fellow who runs the cupola in the foundry. I happen to remember a General Electric man discussing with me a positive blower that didn't furnish volumes of air; it furnished pounds of air, constant pounds. Now why? Because those men know that the volume of air will change with the temperature and with humidity conditions. You have to meet that condition in your blast furnace and in your cupola, and you have to meet it in your open hearth when you use a ratio control.

The blast furnace man makes his record in March and October. Why? Because the atmospheric conditions are right for it. In the summertime watch his production go down 10 or 15 per cent. He speeds up his blowing engine in an attempt to get the same pounds of air, but most of the time the engines are running about as fast as the insurance company wants them to run.

Now really, combustion control men, isn't it a fact that it has been too hard, and you have chosen the easiest way? Hasn't it been too hard to get automatic combustion control by the means of the products of combustion? That is a fact. We have ducked the hard job. Well, you fellows today are drawing your salaries. Why? Because your management hasn't ducked the hard work. They are biting off chunks here and there, and you are going after it. That is the reason you are here today. They are watching the swindle sheets a lot closer.

Well, we have to bite off the hard job if we want to get what we want. The combustion control people are not giving it to us. I think it was five, maybe six years ago when we started taking up this question. We developed different oxygen recorders in our plant. We developed the first one on the chemical analysis of the gases. We got it working, but it was too hard, too costly, the way we had it going. It may be redeveloped along better lines. Then we went at it from a different angle, and we got it.

The machine belongs to someone else; it doesn't belong to me. I could tell you about it if it did. But gentlemen, the oxygen control is possible and is necessary for several reasons.

For the sake of this discussion admit with me that we have the sampling tube in a good location. Lets just say that, and that we can catch any changes which occur in the general products of combustion. Taking any fuel with which we are familiar, say Coke Oven gas, we find that the ultimate CO_2 in this gas is 11 per cent. Now taking flue gas analysis as fast as they can be taken we find that during the melt down that we have 10 per cent CO_2, and 1 per cent oxygen. Excellent combustion. Then the lime boil begins and if we supply additional air to care for the gases coming from the bath, in about an hour the CO_2 goes up to 15 or 16 per cent. This of course, is 4 or 5 per cent above the theoretical. The lime boil is working well and in a couple hours more the CO_2 starts to drop and again gets down to 10 per cent with 1 per cent oxygen. Of course, you have a man working an orsat on the products of combustion and telling the first helper what air adjustments to make.

The next heat doesn't work the same, something is wrong the boil picks up slowly and drags out several hours longer, but the orsat tells us how to adjust the air supply so we have good combustion, even though the CO_2 only goes up to 13 per cent.

But what would happen if there was no orsat, just a ratio control. Is the first helper expected to be clairvoyant? How much should he change the manual adjustment on the ratio control to get the proper amount of air, and how long should he leave the adjustment in that position. Then again will he make the change at the correct time or will he forget and allow unburned CO to pass on into the checkers, there to burn when mixed with infiltrated air at that point; or if he makes the change correctly for one heat, how will he know what change to make for the next heat. They all work differently. If the helper tries to take care of unburned gases that are not there you will have excess air carrying

heat up the stack. Believe me there is plenty. Mr. Dickey's paper indicated that to you.

I don't know whether you got the significance of the upper curve on his chart, but as the excess air in the stack went up, the flue gas temperature went up, so you have the increasing loss. That is a good one to remember.

You can get a saving in fuel with your present automatic combustion control, but you are not going at it completely. You are going at it the easiest way. What you operators want is not what they are giving you. What you want is control by products of combustion to make all the gain instead of just a part.

It so happens we haven't got an automatic combustion control in our Ashland plant; I can speak freely. We are going to have, but we want to get what we want, instead of taking what these sales representatives want to hand to us on a platter. And I believe if you operating men will get together you will get what you want.

The question of control of atmosphere in an open hearth furnace has been discussed many and many a day in the open hearth office. Do we want reducing during the melt-down? Do we want oxidizing? Do we want neutral? What do we want in the lime boil? You have all talked about it. Nobody knows. That is a secret. There isn't an open hearth man today who can tell you what he wants over the bath in any heat. He might tell you what he wants for this heat, just to see how it works. But that is a fact. He doesn't know. Until he does know, the thing to do is to go after fuel economy. When the metallurgist knows, he will tell us, and we will give it to him.

I am sorry if I have ruined any of your sales, gentlemen. But I felt that, while it is a little outside of the subject of the symposium this afternoon, it is a subject that has been whispered behind closed doors and to one another, and I think it is time for us to come out in the open with it and ask you to give us what we want.

H. A. Winne: I am not going to talk about how to control an open hearth furnace. I don't know how. But there have been some statements made relative to hydraulic or mechanical versus electrical devices that I can not let stand without saying something.

Mr. Shadgen, I believe, stated that it was impossible to obtain an electrical equivalent of the well-known hydraulic control with follow-up motion, whereby the operator moves a small lever and gets a corresponding movement on a large piston somewhere else. Is that correct?

J. F. Shadgen: Yes, it is.

H. A. Winne: I am afraid I will have to take exception to that statement, inasmuch as 12 years ago the General Electric Company built for a Southern steel mill an electrical equipment for driving the intensifier of a hydraulically operated shear. A 700 H.P. reversing motor drives, through a rack and pinion, the piston of the intensifier. The operator has a controlling lever, and the position of the piston corresponds to the position of the lever. When he moves the lever a certain amount the motor rotates and drives the rack a corresponding distance. The speed of the motor is greater for large movements of the lever than for small. I think here we have certainly the equivalent of hydraulic control with follow-up motion.

Today we are prepared to furnish equipment in which the operator may use a small control lever, and when he moves that lever a motor which may be located 10 feet or 1000 feet away—a motor of 1 H.P., 10 H.P., or 1000 H.P.—rotates an amount in exact proportion to the movement of the lever. We can arrange the control so that if the lever is moved a small distance the motor will rotate at a slow speed a corresponding number of revolutions, and if the lever is moved a greater distance the motor will rotate at a faster speed for a corresponding number of revolutions.

This gives control which is fully equivalent to that which can be obtained by any system of pilot valves and hydraulic cylinder, with this improvement. With the hydraulic system there must be, I believe, a mechanical lever connection between the pilot valve, the controlling lever, and the operating piston, in order to get the follow-up motion. With the shear intensifier equipment, which I spoke of, we also had a mechanical connection between the controlling lever and the operating piston. However, with the electrical system, as we are prepared to furnish it today, the only connection required between the controlling lever and the device which is being operated consists of five or six small control wires, which are a lot easier to carry around corners and across furnaces, and so on, than are mechanical connections.

Mr. Simpson, I believe, made the statement that it was not possible to obtain electrically a system whereby the rate of speed of the operating element would be proportional to the amount of movement of the controlling element. As I said previously, we have already developed such electrical systems. One is in connection with a wire drawing operation, which may seem rather remote from open hearth furnace control, but nevertheless it illustrates the principle. In this arrangement we have a pulley riding on a loop in the wire between the last die and the reel. That pulley has a little iron core suspended from it so that it can move up and down within a small coil of wire. The position of that plunger, moving through a distance of 1" or 2", determines whether the motor driving the wire reel is standing still or running at 1700 r.p.m. The speed of the motor is proportional to the position of the plunger.

So I think we can do electrically almost anything that can be done with hydraulic controls. To my mind, the question of whether you should use hydraulic or electric means of operating such devices depends largely on the distance between the controlling device and the piece of apparatus which you want to operate. If it is very short, the mechanical system is usually the simplest. We see lots of houses built today with door knockers on the front door, but I never saw one electrically operated. They are all mechanically operated. On the other hand, I have yet to see a house built recently in which the door-bell, if it is placed inside,—that is remote from the controlling lever,—is operated other than electrically.

On our steam turbine governors, for example, we use the hydraulic method of operation. The controlling means, i. e., the centrifugal device, is very close to the valves which are to be operated, we have

oil pressure available which is required for lubrication of the bearings, and therefore we make use of the hydraulic system. However, on these same governors there is a means for adjusting the operating speed of the turbine so that the generators of different sets may be synchronized and, as this must be controlled from the switchboard remote from the turbo-generator, it is electrially operated.

It seems to me that future developments in the methods of operating valves, dampers, etc., will be along electrical rather than mechanical or hydraulic lines. In looking a long way into the future, it seems to me quite possible that you may see a little office located where it commands a good view of the open hearth furnace floor; in that office will be seated an operator. Before him he will have a good many indicating instruments showing conditions in the various furnaces at all times, and at his finger tips he will have the control of the operation of these furnaces. When that time arrives the whole control is certain to be electric.

W. C. Buell, Jr.: The subject of open hearth control is of great interest to us and I am glad to have had the opportunity of hearing from the speakers on this subject. I have a few comments which are here offered.

It seems to me that the last speaker, Mr. Bradley, gave us the best idea of the afternoon when he stated in substance that all control of the furnace must be subservient to, first, the metallurgical and, second, the productive operation of the furnace. In steel making, fuel cost and furnace upkeep cost probably rank third and fourth respectively in the order of their importance as operation factors in the mind of the open hearth superintendent. In the past, at least, those offering control equipment have stressed the fuel saving possibilities to the exclusion of the more important factors of operation. The difference in fuel cost between very poor practice at, say, 6,000,000, and excellent practice at 4,000,000 B.t.u. per ton, is probably not more than forty cents; which, while on its face is worth while saving, may not be worth while saving if it imperils quality or tonnage.

During the past couple of years I have had the opportunity to be associated in the design of about twenty-five 150-ton open hearth furnaces. All of these furnaces have had plated regenerators and fan tails and the last fourteen have had plated slag pockets and uptakes to the charging floor line. Air infiltration, which has been touched upon a number of times this afternoon, will not be a factor in these modern furnaces; first, on account of the plating, and second, because forced draft will be employed which will allow an above atmospheric pressure throughout the entire system at all times, if willed by the operator.

I have a record of a 130-ton furnace which I worked on about three years ago, and upon which very careful operating data has been continuously taken. On the last 900 heats the average oxygen in the waste gas at the stack is 4 per cent (about 20 per cent excess air) and there is no draft control on the furnace. As metallurgical requirements ordinarily call for oxygen in excess, it is doubtful if the operation of this furnace could be materially bettered. However, within the past few years I have seen furnaces in several plants operating with great infiltration and with the waste gas showing as high as 300 per cent total air. Any new equipment or change in method would undoubtedly show a marked improvement on such a furnace but the equipment maker should not draw the conclusion, as many are prone to do, that such an improvement would follow the installation of their equipment on any furnace.

The furnace designers have not been inactive the past few years. Only a decade ago it was not unusual to find furnaces requiring seven million B.t.u. and producing seven or eight tons per hour. All well designed furnaces built in the past couple of years are operating at less than four and a half million, several are operating at slightly over four million, and thirteen to sixteen tons per hour is the rule. Refractory costs are down to as low as 7 pounds to the ton.

Fourteen 150-ton furnaces which are to be constructed shortly have been designed, after taking credit for steam, to operate at 3,600,000 B.t.u.

In all of the modern furnaces, control has been incorporated where the furnace designer has felt it could be advantageously applied.

Excepting pressure control of the entering fuel which is generally applied, I think that at least 80 per cent of all the benefit that will accrue from complete control will come from the use of draft control alone. Experience has shown that devices for proportioning fuel to air and fuel to fuel, if installed, seldom remain in operation after a few months.

I think that many casual observers look upon the making of steel as a possible mechanical process and controllable as such, but to anyone who has worked on the charging platform it is an art, and in the minds of competent observers, it will always remain an art, and as such must be under manual and mental control.

I am in doubt as to the merit of full automatic reversal. While at certain times during the heat, principally during the refining period, the reversals may be quite regular, at other times, during the melting period, it may be necessary to reverse at irregular intervals to save undue action on the roof, and during the finishing period short reversals may be in order to increase bath temperature, and accordingly no stated cycle of reversals can be safely set up.

A push button operated multi-control relay, which when operated will reverse all the elements of the reversal apparatus in their proper order and time sequence, should be used, but in the present stage of the art this push button should be operated manually rather than on any arbitrary automatic system.

G. M. Coughlin: I want to say a word in reference to the point brought up by the last speaker. The question of air leakage from checkers when they are under pressure is just as bad as air infiltration when the checker system is under less atmospheric pressure.

While we have modern furnaces today—and I must say that we have very few of them—the problems that the control men are going to meet are largely problems of old furnaces. Whether they are under forced draft or the draft brought about by the uptake matters not. If you have a leaky furnace, you have a weak spot in your control, because those leaks do not stay constant. If you supply enough air for the present, when you start your furnace on its campaign, when you are not supplying enough

air three weeks later and three weeks later than that, and so on, and you have to run your test and make your adjustments quite frequently, whether you are under forced draft and have air loss from your checkers or induced air from the uptake alone and infiltration.

W. C. Buell, Jr.: With forced draft and measuring instruments and with fuel quantities known, air leakage is easily measured.

G. M. Coughlin: The trouble is you don't know what you are losing. You can only tell by analysis. They will give the quantity you put into the new system, but they don't tell how much leakage there is.

W. C. Buell, Jr.: Unless you keep track of the metered quantities.

G. M. Coughlin: It is based on the analysis of the products of combustion. That is the way you check it.

J. F. Shadgen: Everybody took a shot at me, and now I will try to get back at you.

First, I want to assure you that I am not selling, and that nobody is making, Automatic Control Equipment. We are making machine control. The machines have to be set by a man, so that is not automatic equipment; it is machine control. I made a plea last year for everybody to call it Machine Control instead of Automatic Control, but only one manufacturer calls it machine control. The others are still making automatic control. Let them go ahead.

Second, we are industrial engineers in a commercial field. We have to make money to live. We can't make a 100 per cent solution and sell it successfully. We have to make a part solution for the easiest part of the problem, until we are able to make a better one. I think that ought to satisfy the Armco man. You can't start with a 100 per cent solution, because it takes too long. By making something practical, and selling it, you are able to improve it and finally develop the full solution.

Third, CO_2 control has been a failure all the way along, because it is upstream control. It is too late. I don't think that question will ever come up, because it is very much harder to swim upstream than downstream.

Fourth, I think most of the gentlemen are misinterpreting Mr. Henry's and Mr. McLoughlin's paper of the Iron and Steel Institute. I have heard many times for the last four weeks the famous remark: "Imagine, to get only 58 per cent of the air through the checkers!" It happens that the tests in the furnace were run at a much higher rate than the furnace was built for. You cannot run any normal furnace if you get only 58 per cent through the checkers. It is usually 80 to 90 per cent, and at the beginning of the campaign it is more. Let us not overemphasize one little opinion out of a whole barrel of opinions and base our opinion on that.

A lot of people have mentioned that figure to me —58 per cent—and they were amazed at it. But you have to look through the whole paper to find the explanation. It isn't as bad as you think. During that test they were pushing the furnace beyond the limits.

The fifth point is especially about Mr. Dickey's paper. I never saw an open hearth run with 150 per cent excess air. If a man puts in 50 per cent air, he won't make any steel, he will make molasses. The temperature will be too low to keep the bath fluid.

Mr. Coughlin mentioned that nobody wants to correct for temperature and humidity. The maximum error is only 4 per cent. We can save more elsewhere on more important errors. That is the maximum you can get from it theoretically. The average is about 1 per cent.

I also notice that whoever develops that device for humidity correction is not very successful with it, because so many of them aren't operating. After all, the equipment has to work, gentlemen. You can draw pictures on the paper, but equipment has to work. That is the hard job. Look at the gray hairs I am getting.

The General Electric man told us how to compensate very nicely electrically. They build turbines but sell you hydraulic compensators. And boys, they love them! The cylinder is a very simple device. It cannot get out of order. The piston runs in oil: "Simplicity and Reliability."

The push button is perhaps the greatest enemy of control, for this reason: The push button brings a man into competition with control apparatus, and control is licked because the man can make alibis. The man is a brain body, while the control equipment is only a machine; it is only an attempt to substitute an apparatus for the man. It is unfair to bring the man into competition with it, because a man has intelligence as well as opinions.

I will give you an example. The control equipment was sold and applied. It worked for eight or ten days and it worked well. The man developed a certain degree of confidence in its operation. Everybody said it was fine. Operators said, "We don't have to touch a thing." Then something started to dance, and in some way it could not be fixed immediately. The man immediately lost confidence in the whole scheme. Up to this day we haven't been able to restore that confidence, just because one little thing went wrong. The operating crews always ask: "Does the control make their work easier?" "Do we make more money with the control working?" It makes operation easier. If it makes their operation easier, then they make more money and more tonnage. The first thing we do when we put a control in, to push up production, because then the men help you. If the production falls below a certain limit which the management has set, then the help is very passive to say the least. They will have all sorts of alibis. There are ninety-nine ways of saying "No," and only one way of saying "Yes." Men are jealous. Men are afraid of their jobs. It is only by educational effort that we can overcome that.

The General Electric man made a very pointed statement, which is correct. It is often a matter of taste. I talk English now because I live in America. I talked French before. Electricity versus hydraulics is largely a matter of taste. But in all fairness, I would like to say we have had years of development mostly on hydraulic turbine and steam engine governors but electrical governing is relatively new. The electrical engineers are persistent, and they will win, but they have not done it yet. So far it isn't here.

My associates have worked for the last three years on electrical governors, but so far we have not

been able to solve in a practical way the compensation feature. We have hopes that we will within a couple of months perhaps, if we are ingenious enough. But so far we have not been able to solve the problem as it has been done on turbines. That is the criterion, because the turbine governors had such a terrible responsibility to shoulder.. But if we get there, we will be the first one to shout about it to the whole world.

M. J. Conway: Are there any other gentlemen here who wish to discuss the papers which have been presented?

Primarily this symposium was planned to bring out all the features of machine control which are at present recognized by the manufacturers and users as contributing to the economy of the manufacture of steel. As is usually the case when a new art is applied to an old process mistakes are made both in design and application, and it is our honest desire as an Association to help minimize these mistakes which ultimately mean money, both to the manufacturer and the user; to the manufacturer by expenditure for blind development, and to the user by purchase of equipment which is unsuitable and soon becomes obsolete and the attendant loss of earning power for which the equipment was purchased. We have today definitely established that control intelligently purchased and applied is a very helpful and profitable addition to the average open hearth furnace.

We have also proved that it can be used without disturbing our furnace personnel and that its influence will shortly improve their knowledge of the furnace combustion process in addition to giving them a continuous record of what is happening in the combustion process, something the furnace man is entitled to know just as much as the boiler tender should know his steam load and pressure. This also enables the furnace man to better supervise the metallurgical process in which he is represented as the indeterminable "human element" in the manufacture of steel.

Our next consideration has been the type of motivating force used in the design of the control equipment. Whether electrical or mechanical? This question has been answered in part by the adherents of both methods but I doubt whether we have yet sufficient concrete information from either side to allow us to make a decision. It is hard to conceive a type of control that would be fully mechanical or fully electrical in average application, and in any case the economies to be considered at the point of application may influence the type of motivating power to be selected.

We are very thankful to the authors who have so fairly presented both sides and who seem honestly concerned in giving us the best design to suit our individual requirements. We cannot overlook the fact that these men have spent a great deal of time and effort to fortify themselves with knowledge of the combustion process of the open hearth and in them we have added to our ranks a lot of strength to aid us in our daily problems. I feel that we have not heard the last word from the electrical division on this subject, and while we are waiting the mechanical division are going to do more.

The papers presented this afternoon have formed an excellent addition to the Combustion Division of the Association and we are grateful to the authors for their efforts.

Items of Interest

PERSONNEL CHANGES

C. E. Bedell, formerly of the Benwood Plant of the Wheeling Steel Corporation, has resigned to accept a position with the Mesta Machine Company as Electrical Engineer.

Mr. Bedell is one of the oldest active members of the Association of Iron and Steel Electrical Engineers and has always been a very liberal editorial contributor in the columns of the Iron and Steel Engineer and the Association's Transactions.

Mr. Bedell has served on many of the national committees of the Association and has always been an active member of the Pittsburgh District.

John B. Sullivan, who was formerly assistant electrical superintendent of the A. M. Byers Company located at Economy, Pa., has been made superintendent of the Electrical Department. Mr. Sullivan is an active member of the Pittsburgh district of the Association and his many friends are congratulating him on his new position.

T. E. Hughes, formerly general foreman of the Electrical Department of the Duquesne Works, Carnegie Steel Co., Duquesne, Pa., has been made an assistant to the electrical superintendent at that plant.

M. S. Robinson with the Erie Malleable Iron Company has been transferred from the Pittsburgh district to Chicago as district manager of the sales of the Chicago territory. Mr. Robinson has always been a very active member of the Association of Iron and Steel Electrical Engineers, joining the organization in 1912. His many friends wish him success in his new connection.

William A. Irvin, vice president of operations, American Sheet and Tin Plate Company, one of the pioneers in the tin plate industry, has been transferred to the U. S. Steel Corporation offices in New York as one of the vice presidents of this corporation.

Albert H. Shonkwiler, assistant superintendent of the Otis Steel Company, Cleveland, resigned September 1 to accept a position with the Steubenville works of the Wheeling Steel Corporation.

Trusten P. Draper has retired as vice president in charge of operations of Sharon Steel Hoop Company, Sharon, Pa., after having been connected with the company for many years. It is likely that his

work will be divided among other executives, under direction of John A. Roemer, president.

William W. West, for the past 10 years with Steel and Tubes, Inc., Cleveland, has resigned as general superintendent of the Elyria division of the company.

John S. Bleecker has been appointed manager of sales of Lukenweld, Inc., a division of the Lukens Steel Company, Coatesville, Pa. He was graduated in 1898 from the Massachusetts Institute of Technology, where he specialized in both mechanical and electrical engineering. Most of his activities since that time have been confined to the executive management of many enterprises for Stone and Webster, Day and Zimmermann and Bates, Inc.

Rockbestos Products Corporation announces the appointment of Russell G. Meyerand as sales engineer in its New England territory.

Mr. Meyerand formerly was assistant to the chief electrical engineer of the Stone and Webster Engineering Corporation with headquarters at Boston. He will specialize on industrial, engineering and central station groups throughout the New England territory.

William F. James formerly manager of the Middle Atlantic district of the Westinghouse Electric and Manufacturing Company with headquarters at Philadelphia, has been appointed assistant to the commercial vice presidents of the Atlantic division. Mr. James has been with the Westinghouse company since 1909. In 1912 he began to specialize in steel mill electrification, in 1923 he became manager of the industrial division, and two years later was made Middle Atlantic district manager.

E. W. Loomis, with the Westinghouse company since his graduation from the University of Delaware in 1914, as manager of the mill and mining section and recently manager of the northeastern industrial division, has been appointed manager of the Middle Atlantic district.

Othmar Karl Marti, formerly chief engineer of the American Brown Boveri Company, Inc., is now associated with Allis- Chalmers Manufacturing Company, Milwaukee, Wis., in the capacity of engineer in charge of rectifiers and railway equipment.

Earl B. Bremer, who has been located for thirteen years in the Chicago office of the Westinghouse Electric and Manufacturing Company, recently as manager of small motors section, has been appointed manager appliance electrification with headquarters at East Springfield, Mass., according to a statement by Fred T. Whiting, northwestern district manager.

The Norma-Hoffman Bearings Corporation—manufacturers of "Precision" ball, roller and thrust bearings, with factory and main office at Stamford, Conn.—announce the opening of a sales office at 1014 American Bank Building, Parkway and Walnut Street, Cincinnati, O. Mr. C. D. Kilham, for many years sales engineer at the home office and later at the Cleveland office, has been made manager in charge.

WITH THE MANUFACTURERS

COMBUSTION STEAM GENERATOR

Combustion Engineering Corporation, 200 Madison Avenue, New York is now offering the Combustion Steam Generator, a standard steam generating unit built in various sizes and providing a wide range of capacities at any desired conditions of steam temperature and pressure. Detail designs have been completed for eight sizes with capacities ranging from 70,000 to 400,000 lb. of steam per hour, from and at 212 deg. fahr.

LARGEST WELDED STEEL CONDENSER

The largest welded steel condenser ever manufactured is now being built by the Westinghouse Electric and Manufacturing Company at its South Philadelphia Works for Public Service Electric and Gas Company, of New Jersey.

This is a 65,000 square foot condenser of the single pass, radial flow, welded steel plate construction and will serve a 75,000 kilowatt, single cylinder Westinghouse turbine generating unit.

SURFACE CONDENSERS

Elliott Company, Pittsburgh and Jeannette, Pa., has issued a new Bulletin C-7 on Surface Condensers. A 24-page book, it contains information on the economics of surface condensers, information on heat transfer, tube layout and design and gives basic condenser formulas, useful charts, etc. It is well illustrated with condensers of various shapes and sizes and representative installation views. A copy of the bulletin will be sent upon request.

TORQUE MOTORS

Slow speed torque motors (or rotating magnets) have several unique characteristics not generally known or appreciated. They may be wound to stand stalled, with current on, exerting their full power for any suitable, predetermined period from 10 minutes out of sixty or 25% or 50% or continuously (24 hours) without burning out or overheating.

They are generally wound so they will rotate at 600 or 1200 r.p.m. if not opposed but they may drive their load at any lower speed determined by the load itself and without danger to the motor.

These motors operate the arm clamp on the radial drill built by the Western Machine Tool Works at Holland, Michigan. The clamp is self-locking so the current to the motor may be cut off when arm is clamped but the motor is wound for 24 hour service so no harm will result if the operator should forget except the loss of a very small amount of power. He reverses the motor to release the clamp.

Thousands of similar motors are in use on elevators to operate the controllers for acceleration or reverse—to operate cams which permit doors to open—to operate the doors themselves—to release the brake mechanisms and for many other purposes.

Some of these motors are used for miscellaneous purposes where power must be exerted to a standstill without harm to the motor such as valve operation and for pumps which operate to maintain a pressure between given limits but there are hundreds of applications where they would be economically and advantageously available if their powers and limitations were more generally known.

These Torque Motors may be wound for D.C. current or for polyphase A.C. current and to a limited extent for single phase A.C. current. They are built to suit each job by The Ohio Electric Mfg. Co. of Cleveland, Ohio, who have had considerable experience in their application and will be glad to co-

operate with anyone who might use such motors to advantage.

TEST CLAMPS

The Trico Fuse Manufacturing Company of Milwaukee recently placed on the market a complete line of high-grade Test Clamps.

These test clamps have been especially designed for accurate testing work although they can be used for general applications such as making temporary connections, battery charging, signal inspecting, meter and motor testing and other shop and laboratory tests.

The jaws are actuated by the turning of a molded knob. All metal parts are cadmium plated to resist rust and acid.

The KLIPLOK Test Clamps are made in four sizes rated 0-30 amp., 30-75 amp., 75-150 amp. and 150-300 amp.

TWELVE-PAGE FOLDER FEATURES BROWN POTENTIOMETER PYROMETER

An attractive 12-page folder has just been issued by The Brown Instrument Company, Philadelphia, showing in tabloid form the principal features of the new Brown Potentiometer Pyrometer. Extreme accuracy and ruggedness is claimed for this new instrument and the folder shows many of the constructional features substantiating this claim. The folder is arranged for easy reading and gives a very good idea of the instrument illustrated. Copies of this folder can be had by writing The Brown Instrument Company, Philadelphia, Pa.

ROLL GRINDERS

Farrell Birmingham Company's booklet No. 107 "Assuring Production With Precision in Roll Grinding," which has recently been published, describes the new conception in Roll Grinders.

This booklet explains the necessity for close accuracy and fine finish in rolls used for the manufacture of various products such as metal, paper, rubber, etc. and how the skill transferred into the mechanism of Farrell Roll Grinders permits the highest attainment of these requirements with a minimum of dependence upon human skill.

The mechanical features responsible for the accuracy and high output of finished rolls are also described. These features are responsible for substantial improvement in the quality of roll grinding and, in many cases, the reduction of roll finishing costs.

It will be noted in the booklet that there are several types of Roll Grinders, each designed for a specific purpose. Each type embodies certain principles of design which promote the efficiency of the machine for the particular work for which it is intended. Write T. V. Busk, Farrel-Birmingham Company, Ansonia, Conn., for a copy.

COMBINATION SAFETY SWITCH AND MAGNETIC CONTACTOR

The Rowan Controller Company of Baltimore, Maryland, manufacturers of completely oil immersed control equipment for electric motors, recently introduced a combination safety switch and magnetic contactor for use with small A.C. motors.

The equipment can be furnished up to and including 5 H.P.—220, 440 or 550 volt. Over-load protection is furnished in other Rowan equipment for those engineers who prefer this feature for small motor operation.

The unit is compactly built, so that it occupies a minimum space and the fact that it is completely oil immersed makes it vapor-proof, weather-proof and dust-tight.

Because of its rugged construction and its completely oil immersed feature, it has aroused considerable interest among engineers in charge of steel mills, gypsum plants, oil refineries, chemical plants and cement plants.

A bulletin giving a complete description of this new combination safety switch and magnetic contactor has been prepared by the manufacturer and is available for distribution to those engineers interested in this type of equipment.

GENERAL ELECTRIC INTRODUCES LINE OF ELECTRIC STEAM GENERATORS

The General Electric Company announces a line of electric steam generators for application anywhere in industry where steam is needed but is not available in sufficient quantities or at suitable pressure. The line includes two pressure ratings—100 and 200 pounds—in various sizes and electrical ratings.

The standard unit consists of a suitable steel container in which one or more helicoil sheath-wire immersion heaters (depending upon the capacity required) are inserted. The generator is provided with standard boiler fittings, including a safety valve, steam gauge, water column, blow valve, steam valve, etc. A typical control equipment consists of a magnetic switch and an automatic pressure governor which, when operated in conjunction with a low-water alarm, automatic heat-shut-off switch and some device for automatically feeding additional water to the generator, makes the equipment completely automatic in operation and obviates any necessity of supervision except for the periodic inspection ordinarily given to any electric apparatus.

Strictly speaking, the normal rating of an electric steam generator is its maximum rating, but additional capacity (in pounds of steam that can be "flashed" for a given interval) can be obtained by incorporating in the design an accumulator capacity. This is attained by raising a larger volume of water to a higher pressure than for normal requirements and providing the electric steam generator with a pressure reducer. Because of this accumulator capacity, a quantity of steam can be flashed without reducing the normal pressure. This arrangement is quite essential when steam demands are large for the initial heating of such devices as process tables, platens, and kettles where speed in heating is required.

A NEW MOTOR STARTER

The Electric Controller and Manufacturing Company of Cleveland, Ohio announces a new motor starter. It is known as the "No. 2 Type ZO Across-the-line Motor Starter," being a companion to the well known EC&M No. 1 ZO Starter.

Like the No. 1 ZO Motor Starter, this new and larger ZO is a self-contained unit, totally enclosed in a heavy (16 gauge) pressed steel case with oil-immersed main and control circuit contacts and

vapor-proof overload relays. The entire unit is of very compact design requiring little mounting space and is of dust-tight construction. The introduction of this starter now provides two standard sizes of oil-immersed, vapor-proof, wall-mounted, extremely compact motor starters.

These features of design make the No. 2 Type ZO Motor Starter perfectly safe for operation in any adverse atmospheric condition. It is not necessary to install this starter in an expensive control room. You can mount it right out in the plant alongside the motor it controls and secure a vapor-proof, dust-tight and shock-proof installation.

This new starter may be used for low voltage release or low voltage protection applications. Standard, vapor-proof, or explosion-proof EC&M push buttons, described in bulletin No. 1105, can be supplied for use with these starters.

NEW PHOTO-ELECTRIC LIGHTING CONTROL RELAY

To enable the intensity of natural light to control artificial lighting automatically, a new photo-electric lighting control relay has been developed by the Westinghouse Electric and Manufacturing Company. When the intensity of daylight decreases to a certain point, this device operates to turn on electric lights; and, conversely, when the natural light increases to a certain intensity, it causes the lights to be turned off.

The operation of the lighting control relay is effected by variations in the intensity of light falling on a photo-electric tube. These variations produce proportional changes in the amount of current passing through the tube; and this changing current, amplified in a specially designed amplifier tube, energizes a primary relay controlling an auxiliary contactor, which, in turn, operates the main contactor controlling the lighting installation.

On the upper side of a micarta panel in a cast-aluminum box, with a glass hood to admit the light, are mounted the photo-electric tube, the amplifier tube, and the primary relay; mounted under the panel are fixed condensers, a transformer, the auxiliary contactor, and potentiometers for adjusting the device for operation at different intensities. Two dials, mounted on a panel on the side of the box, are used for regulating the potentiometers, one controlling the intensity at which the device turns on lights, and the other the intensity at which it turns them off. The foot-candle range of these dials is varied by a three-position plug switch located between them.

Some of the many applications for this device are found in providing automatic control for lights in office buildings; show windows; signs; schools; and in floodlighting, street lighting, airport lighting, and navigation lighting installations.

With a photo-electric lighting control relay installed in an office or a factory, variations in natural light can never interfere with good working illumination on any day of the year, since control of the lights is entirely independent of individuals' judgment, which is usually inaccurate. The use of this relay also effects savings in power; it has been found in several installations that automatic control of factory interior lighting has saved approximately one-half of the power needed without such control.

Automatic control applied to illuminated signs and show windows effects a maximum of advertising value, since it turns on their lights whenever artificial lighting can increase their visibility and turns them off when artificial illumination fails to enhance their attention-getting power. During early morning hours, usually from one to five o'clock, a time clock may be used to turn off the lights, a combination of the lighting control relay and a time clock giving complete automatic control of illumination.

Leaflet 20513 published by the Westinghouse Electric and Manufacturing Company describes the photo-electric lighting control relay, giving application, operation, construction, and installation details.

NEW EXPLOSION PROOF A.C. STARTER

A new, explosion proof, across-the-line, automatic starter for A.C. squirrel cage induction motors is announced by Cutler-Hammer, Inc., 259 No. 12th St., Milwaukee, Wis.

Distinguishing this new starter from similar explosion proof equipment is the immersion in oil of its new thermal overload mechanism. It differs from the usual immersed oil dashpot relay and three-pole magnetic contactor in that a newly designed thermal overload mechanism is used with the contactor.

The new starter is designed in keeping with the latest requirements of the Underwriters Laboratories for Class 1, Group D, Hazardous Locations. Briefly, this includes such installations where Duco, lacquers, gasoline, alcohol, etc., are present in the atmosphere.

The contacts of this new starter open under a 6" head of oil. A special provision is made for bringing all incoming wires to the terminals below the oil level. A float operated oil indicator shows the oil level. Threaded conduit openings and a compound filled junction box are included.

The supporting structure is arranged for wall mounting and the tank is easily removed.

Being completely oil immersed, the starter is corrosion resisting and therefore suitable for chemical plants and cement mills. General applications are: dry cleaning establishments, oil refineries, gasoline pumping stations, lacquer spray rooms, gas plants, flour mills, grain elevators, starch mills, sugar mills, and coke plants.

PLANS FOR NEW $550,000 ELECTRIC PLANT

Announcement was made recently of what is claimed to be the largest industrial development in the Chicago area during 1931. Jefferson Electric Company purchased a 19-acre tract in Bellwood, a western suburb, on which it will erect at once a $550,000 manufacturing plant. This will house in one building their two Chicago plants now at 15th and Leflin Streets and at Congress and Green Streets, and will care for their entire business with the exception of its Canadian subsidiary in Toronto. The company now employs approximately 1,800 and the new plant will have facilities for 3,000 workers.

PHOTO-ELECTRIC RELAY OPERATES SHEAR FOR CUTTING HOT BARS AT BETHLEHEM STEEL PLANT

One of the new uses of the photo-electric relay is to be found at the Lebanon Plant of the Bethlehem Steel Company, Lebanon, Pennsylvania. Here the device is used in the process of cutting hot bars to hot bed lengths of approximately 150 feet as the

bar passes from the last stand of rolls to the hot bed. The desirable features of this device as contrasted with the mechanical flag switch, are that it is more readily adjustable along the hot run-out conveyor to obtain accurate lengths of bars sheared for the hot bed; and that the time element between the arrival of the bar at the photo-electric tube and the operation of the Rendleman shear is more constant than in the case of the mechanical flag.

The use of an adjustable time relay was first considered, to provide intermediate rod lengths, but as it was necessary to provide for lengths increasing by increments of six inches, and as the rod travels at a maximum speed of 1,200 feet per minute, this meant a relay with a minimum time of 1/40 second and adjustable in similar increments.

By the use of the General Electric photo-electric relay it was found the equipment could be made to operate satisfactorily. When the front end of the hot bar passes beneath the photo-electric tube, there is enough light emitted from the bar to increase the current flowing through the tube and thus actuate the relay. The photo tube is mounted above the run-out table at any predetermined point suitable for causing a cut of the proper length, and is easily movable along the table to provide for different lengths.

The change in current in the photo-electric tube is amplified by a Pliotron tube mounted in the relay box some distance away. The amplified current energizes a sensitive relay in the box which causes two magnetic contactors to close. One of these operates the solenoid which throws the trough of the Rendleman flying shears and cuts the bar to the length desired. The other contactor energizes the a-c. coil of an induction type time element overload relay. After a predetermined time, which may be adjusted to suit the requirements, the induction type overload relay closes a 220-volt d-c. circuit which operates another magnetic contactor. This contactor controls the circuit to the magnetic clutch which engages the kick-off motor. Limit switches on the kick-off mechanism start the bed rocking mechanism, stop the kick-off mechanism after it has completed the cycle and provide interlocks as heretofore. The object of the induction type overload relay is to provide the necessary interval of time between the shearing and kick-off to allow the bar to reach the proper position in the hot run-out trough before being ejected upon the bed.

DIRECT-CURRENT VERTICAL MOTORS

The Reliance Electric and Engineering Company, Cleveland, Ohio, have developed Type T. Direct-Current Motors for vertical operation in sizes up to 50 hp., 1150 r.p.m.

These motors are provided with a ring base for mounting and a drip cover to protect them from falling dirt and chips and from dripping water, oil or other injurious solutions.

Where it is desirable the motor can be mounted direct to the machine being driven without the ring base and appear as an integral part of the machine.

Amply large bearings are used to take up the thrust load or weight of the armature. Two heavy eye-bolts are provided to make handling easy. In all other ways the construction is the same as the Reliance Type T, Direct-Current, Heavy-duty Motor for horizontal operation.

OBITUARIES

Alva C. Dinkey, president, the Midvale Company, Philadelphia, and former president of the Carnegie Steel Company, died at his home in Wynneswood, Pa., August 11. The immediate cause of his death was heart trouble. He had been in a weakened condition since an attack of pneumonia three months ago.

Mr. Dinkey, who was born at Weatherly, Pa., February 20, 1866, entered the service of the Carnegie Steel Company as water boy at the Edgar Thomson works in May, 1879. Leaving the company in 1885, he returned four years later as secretary to the superintendent of the Homestead works. He became general superintendent in 1901 and on August 1, 1903, was elected president of the Carnegie company.

In 1915 Mr. Dinkey resigned, becoming president of the Midvale Steel and Ordnance Company. When in 1923 some of the Midvale properties were acquired by the Bethlehem Steel Corporation, he headed up the remaining properties known as the Midvale Company, a position he retained until his death.

Mr. Dinkey was a director of the Midvale Company, the Baldwin Locomotive Works and the American Iron and Steel institute. He was a member of the Carnegie Veterans association and an honorary member of the Association of Iron and Steel Electrical Engineers.

Dr. H. P. Davis, vice president of the Westinghouse Electric and Manufacturing Company, and chairman of the Board of Directors of the National Broadcasting Company, died at his home in Pittsburgh, Pa., on September 10.

Dr. Davis underwent an operation several months ago, and did not recover from the strain. He was 63.

At the time of death Dr. Davis was in charge of radio for Westinghouse, the guiding genius in the development of Station KDKA from a tiny transmitter under a tent in East Pittsburgh to a $700,000 transmitter at Saxonburg, and the addition of short-wave Station W8XK and four other leading stations of the nation.

With Frank Conrad, Dr. Davis made possible the first successful vocal radio broadcast in 1919.

In 1890 he had earned his mechanical engineers' degree at Worcester Polytechnical Institute, and a year later recieved his electrical engineers' degree. His alma mater awarded him the honorary degree of doctor of engineering.

Having acquired his two engineering degrees the young technician came to Pittsburgh to enter the detail engineering department of the Westinghouse plant in 1891.

His rise was rapid. He was appointed assistant chief engineer. In 1904 he became manager of engineering, and in 1909 he was made assistant to the first vice president.

In 1910 he was made vice president in charge of manufacturing and engineering.

In radio and other electrical lines he held scores of patent rights.

DISTRICT OFFICERS AND COMMITTEEMEN

« « 1931-1932 » »

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